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EXPLORATIONS AND SURVEYS FOR A RAILROAD ROUTE FROM THE MISSISSIPPI RIVER TO THE PACIFIC OCEAN.

WAR DEPARTMENT.

ROUTE NEAR THE THIRTY-SECOND PARALLEL, FROM THE RED RIVER TO THE RIO GRANDE,

EXPLORED BY BVT. CAPT. JOHN POPE, TOP. ENGINEERS, IN 1854.

REPORT

ON

THE GEOLOGY OF THE ROUTE,

NEAR THE THIRTY-SECOND PARALLEL:

PREPARED FROM THE COLLECTION AND NOTES OF CAPT. POPE,

BY

WILLIAM P. BLAKE,

GEOLOGIST OF THE OFFICE OF THE UNITED STATES PACIFIC RAILROAD SURVEYS.

WASHINGTON, D. C.

1856.

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WASHINGTON, D. C., *December,* 1855.

SIR: I herewith submit some observations upon the geology of the region explored by Captain Pope, near the 32d parallel, in 1854, based upon the collection of rocks and fossils which were placed in my hands by you for description.

This collection of rocks, taken from various points along the route, is very interesting and complete, and doubtless presents a fair view of the mineral characters of the formations. A list of the collection, and descriptions of the most important specimens, will be found in this report. The fossils, although not numerous, are from interesting localities; but there are no species which have not been previously described and figured.

I have made free use of the descriptions of the main features of the country contained in Captain Pope's report; and in the absence of all geological sections, I have been guided by the topographical and general descriptions in assigning the boundaries of the different formations.

Respectfully, yours,

WILLIAM P. BLAKE,
Geologist of the Office of the U. S. Pacific
Railroad Explorations and Surveys.

Captain A. A. HUMPHREYS,
U. S. Topographical Engineers, in charge of the
Office of U. S. Pacific Railroad Explorations and Surveys.

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REPORT.

CHAPTER I.

General Remarks on the Physical Geography of the region explored.

Extent and boundaries of the region.—Mountain ranges.—Trend and elevation.—Table-lands, their extent and elevation.—Llano Estacado.—Two slopes of the plain.—Altitude.—Bluff character of its northern borders.—Limit of the Llano on the east.

THE strip of country explored by Captain Pope, extending from Preston, on the Red river of Texas, in a direction south of west, to the Pecos river, and thence nearly west to the valley of the Rio Grande at El Paso and Doña Ana in New Mexico, embraces within its limits geological formations of great variety and interest. Its western end is crossed by the ranges of the great central mountain chain of the continent; its eastern reaches to the comparatively low plains of the Red river; while the central portion of the route is upon the extended and elevated desert plain of the Llano Estacado.

As it is very desirable and interesting to note the connexion of the geology with the prominent physical features of the region, I purpose to precede the more particular geological descriptions by some general remarks, based upon the observations of the survey, and which are given in the profile of the route.

The physical features of the region, though strongly marked, are very simple. On the west, the mountain ranges break the monotony of the plains, and form, by their numbers and parallelism, a series of longitudinal valleys extending nearly north and south; but to the eastward of these, and over the greater part of the country Captain Pope traversed, an almost unbroken horizontal plain is found.

These mountain ranges are three in number, and are there known by the following names: Organ mountains, Hueco mountains, and Guadalupe mountains. The prolongations of these ranges towards the north at Albuquerque and Santa Fé have other and local names—Sacramento mountains, Sierra Blanco, &c.; but the whole series form a part of the main central chain, known in its northern portions as the Rocky mountains. The general direction or trend of the Organ mountains and the Hueco mountains is north and south—the former deflecting slightly towards the west. The Guadalupe range, however, does not conform to this direction, but diverges and trends towards the east; its mean direction, as it is given upon Captain Pope's map, being N. 38° E. According to the report of Lieutenant Garrard[1], this range extends southeasterly for seventy or eighty miles beyond the high peak, becoming more impassable as you proceed southward, and finally uniting with a chain of mountains having a northwest and southeast trend. The point which has generally been considered as the termination of the range, he found to be a spur running out into the Salt Plain. The northern terminus, according to Captain Pope's observations, is about sixty miles north of the 32d parallel, where it

[1] Report of Captain Pope, page 63.

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sinks into the valley of the Pecos. I do not find an estimate of the general elevation of the range, but the summit of the Guadalupe Pass, one of the lowest, was found to be 5,717 feet above the sea;[1] while the Hueco Pass is 4,811 feet; and the pass in the Organ mountains, between Doña Ana and San Augustin spring, is 5,467. In fact, the Guadalupe Pass is the highest point Captain Pope reached on his whole line. It is important to note here, that the Witchita mountains, explored by Captain Marcy and Doctor Shumard, and found to be of granite, are located directly in the line of trend of the Guadalupe mountains, and their geological connexion is thus indicated. The outcrop is, however, very distant; but other knobs of granite in a line with, or parallel to, the Witchita mountains, indicate that the general trend of the granitic axes or elevations of that region is N. E. and S. W.; and this favors the supposition of the prolongation or connexion of the Guadalupe chain with the Witchita. We should thus expect to find either more outcrops of granite between the end of the Guadalupe and the Witchita mountains, or a very perceptible modification of the surface of the Llano.

The intervals between the mountain ranges, which are crossed by the line of survey, being occupied by high table-lands, the altitude of these ranges above the surrounding surface is not great. Captain Pope has described three table-lands, rising one above the other towards the east; their greatest width being at the northeast, and their inclination being very gentle towards the southeast; while on the west they terminate in abrupt descents, the three mountain ranges just described forming their western limits. Two of these table-lands are west of the Guadalupe mountains, and are comparatively narrow; the first, from the Rio Grande to the Hueco mountains, being 25 miles; and the second, from the Hueco mountains to the Guadalupe Pass, being about 80 miles in width. The average elevation of the first, deduced from Captain Pope's numerous observations for altitude, is 3,963 feet, being the mean of 12 determinations at distant points. This plain must be remarkably level, and well deserves the title of *Mesa*, which it receives; for the greatest difference in altitude between the 12 stations, from the summit or edge of the plain to the Hueco mountains, is only 56 feet; the highest station being 3,991 feet, and the lowest 3,935. The second plain is more elevated; and yet its lowest point, at the Ojo del Cuerbo, (3,893 feet above the sea,) is lower than any recorded on the first, and is, at its eastern side, near the Guadalupe mountains. The slope of the plain, from the summit of the pass eastward, appears to be very gradual, and, with one or two exceptions, is remarkably regular. One of these exceptions is at the base of the Sierra de los Alamos, which consist of isolated mountains rising above the general level of the plain. The mean altitude of this plain on that line, according to the measurement of the survey, may be considered as 4,250 feet.

The western limit of this plain is the range of the Guadalupe mountains, and beyond them, to the east, is the broad area of table-lands and semi-deserts, reaching to the Cross Timbers of Texas. We here find the great Llano Estacado, or Staked Plain, an elevated treeless waste, 125 miles in width, on the line of Captain Pope's survey. The observations for altitude show that this plateau is remarkably level, and is unbroken by hills or sudden undulations of the surface. The profile shows one great swell of the surface between the Pecos and the Colorado, forming two long, but very gentle slopes, similar to the slopes and counter-slopes of mountains and continents; that on the east being 130 miles in length, while on the west it is only about eighteen miles. The two extremes of this undulation at the beds of the rivers appear to have nearly the same elevation—about 4,000 feet; and the highest point between them—the "summit" of the Llano, as it is called by Captain Pope—is 4,706 feet. From Captain Pope's observations of the general bluff character of all the plateaux towards the west, and the consideration of the topography of the country further north, I have been disposed to regard this shorter or western slope as resulting from the erosion of the river Pecos, and to consider the gradual slope eastward from the summit as formerly continuous up to the base of the Guadalupe mountains, forming a uniform slope, similar to the two further west, which have been before described. It is, however, possible that this great undulation of the Llano, represented in the

[1] The elevation of this Pass is reported by Mr. A. B. Gray to be 4,897 feet. [Railroad Record, No. 136, Oct. 1855, p. 27.]

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profile, is not caused by erosion alone, but that a gentle curvature of the strata exists in consequence of the presence of a line of elevation in the older rocks parallel with the Guadalupe range. Such a line of elevation, although far beneath the surface, is very probable; and the extended and gradual, but decided, elevation shown in the surface of the Llano, if it be not due entirely to the denudation and erosion of the Rio Pecos, favors the supposition. Such a line of elevation would produce a basin-shaped or trough-like disposition of the upper strata, even if they rested undisturbed, as originally deposited; and thus the conditions necessary to the success of artesian wells would be obtained.

The mean altitude or general elevation of the great plateau of the Llano has never yet been given. The numerous measurements of the survey, however, furnish the means of determining this elevation, at least for that portion along the route near the parallel of 32°. If we take the mean of the altitudes of 22 stations, from two to seven miles apart, between the Pecos, at the mouth of Delaware creek, and the Sulphur springs of the Colorado, we obtain, in round numbers, 4,500 feet as the mean altitude of the Llano along the line explored. A consideration of the courses of the rivers—the Pecos, Colorado, and Brazos—and the observations concerning the slope of the Llano, lead to the conclusion that the surface rises towards the north and northwest; or, in other words, that the Llano is highest in the northwestern portions, and descends gently, not only east, but southeasterly, towards the Gulf of Mexico. The sources of the Pecos river, at Hurrah creek, according to the observations of Lieutenant Whipple, who passed along the Canadian river, near the parallel of 35°, are at an altitude of about 5,000 feet; and this is over 200 miles north of the point at which Captain Pope crossed the stream. His observations upon the altitude of a portion of the Llano, between Amarillo and Rocky Dell creek, (longitude 102° 30′,) range from 4,128 to 4,400 feet; while the observations of the altitude of the summit, on the 32d parallel, almost directly south of that point, shows a height of 4,700 feet. These results are not consistent with the conclusion of the descent of the surface of the plain from the north to the south.

The formation of the Llano Estacado is one of the most marked physical features of the American continent. Its surface, rising over a broad area to an altitude, in almost every part, of over 4,000 feet, at the lowest estimate, and but little broken or traversed by river valleys, constitutes one of the most perfect examples of an elevated plateau, or *mesa*, that is found. The Great Basin, although generally supposed to be the broadest and most extensive plateau of the country, is entirely different in its character, being formed, not of extended and horizontal layers of rock, but of the *débris* and wash from the thousand mountains and ranges that rise at intervals from its surface, and only by their intersecting slopes produce that general elevation of the surface which has been regarded as a plateau. The Llano, on the contrary, is not broken by a single peak; and there is nothing to break the monotonous desert character of its surface, except an occasional river gorge or cañon, invisible from a distance, and often apparent only when the traveller stands on its brink.

According to the observations of Lieutenant Whipple, this great plateau continues beyond the valley of the Canadian far to the northward, and, although much cut and denuded by rivers, the table-like hills, with mural faces seen on all sides, show its former continuity. The borders of the plateau at the northward, along the Canadian and Red rivers, are well defined by a long line of vertical bluffs, rising like walls above the general level of the bordering country or river valleys. These are described by Captain Marcy in his report,[1] and were seen by Lieutenant Whipple as he approached the Llano from the east. Captain Pope has, however, ascertained that along the line of his survey this characteristic of the plain at the north is absent, and that, instead of a mural face on the west and east, the ascent from the level of the Pecos is very gentle, and "the summit-level was attained at a distance of thirty-five miles, without an abrupt ascent at any point, and without the appearance of any of the marked characteristics which had

[1] Exploration of the Red river of Louisiana, by Captains Marcy and McClellan, U. S. A. [Ex. Doc., 33d Cong., 1st sess.: Washington, 1854.]

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been attributed to it. The descent from its summit to the headwaters of the Colorado was so gentle as only to be perceptible to instrumental survey; and there was nothing to mark its eastern limit, except the existence of the tributaries of that stream. Neither bluff nor uncommon swell of the ground marks its existence as you approach from the east or west, nor is its uniformity of surface disturbed at any point between the Pecos and the Colorado."[1] These observations are exceedingly interesting, and of importance to the question of the location of a railroad. It is possible, however, that this gentle inclination or descent from the surface of the Llano, both on the east and west, is local, and caused by peculiar erosions or degradation of the plain at those points. The Colorado river, at the eastern border of the plain, has numerous affluents; and it is to their continued wearing action that we may look for the destruction of the abrupt precipices which mark the Llano at other places. The regular swell of the Llano, as exhibited on Capt. Pope's profile, may thus result entirely from extensive lateral erosions along that portion of the Pecos, and not be due to the presence of a subterranean ridge of older rocks, as has been suggested.

According to the profile which Captain Pope has presented, the elevated plain of the Llano may be considered to extend from the Guadalupe mountains, or the Pecos, to a point beyond the Colorado, or the divide between it and the Brazos river. This point is 4,236 feet in altitude, and from it the surface descends very regularly for nearly 275 miles, to the banks of Red river, at the termination of the line of survey, only 641 feet above the tide-level.

In the descriptions by Captain Pope, however, he regards the sources of the Colorado, or the Sulphur springs, as the eastern limit of the Llano; and the character of the country indicates a change in the nature of the rocks and soil. I have, therefore, concluded that the geological formation composing the surface of the Llano does not extend on the line of the trail to the east of the Sulphur springs, and I have so represented it upon the geological map.

Rivers and streams.—The principal streams which traverse or take their rise in the Llano, are the Canadian and Red rivers, the Brazos and Colorado, and the Pecos. The first named flows from its sources in the mountains near Santa Fé, almost directly east, and intersects the Llano; the Pecos, also rising in the same place, flows not across the plain, but southerly, parallel with the mountain ranges, forming a long valley of erosion. The other rivers appear to rise near the eastern margin of the plain, and are formed by the union of numerous minor affluents, after they emerge from the cañons of the plateau. With very few exceptions, wherever these streams traverse or intersect the Llano, they are characterized by bold, bluff banks or walls, on either side, which are almost impassable, and confine the traveller to the tortuous course of the stream; while, above, the level surface of the plain stretches out and affords a boundless prospect in every direction. The vertical banks near the sources of Red river are graphically described by Captain Marcy in his report, as follows: "The gigantic escarpments of sandstone, rising to the giddy height of 800 feet on each side, gradually closed in until they were only a few yards apart, and finally united overhead, leaving a long, narrow corridor beneath, at the base of which the head spring of the principal branch of Red river takes its rise." * * * * "The stupendous escarpments of solid rock rising precipitously from the bed of the river to such a height as for a great portion of the day to exclude the rays of the sun, were worn away by the lapse of time, and the action of the water and the weather, into the most fantastic forms, that required but little effort of the imagination to convert into works of art, and all united in forming one of the grandest and most picturesque scenes that can be imagined." * * * * "Occasionally might be seen a good representation of the towering walls of a castle of the feudal ages, with its giddy battlements pierced with loop-holes, and its projecting watch-towers standing out in bold relief upon the azure ground of the pure and transparent sky above. In other places, our fancy would metamorphose the escarpments into a bastion front, as perfectly modelled and constructed as if it had been a production of the genius of a Vauban, with redoubts and salient angles all arranged in due order."[2]

[1] Report of Captain Pope, p. 9. [2] Exploration of the Red river by Captain Marcy. [33d Cong., 1st sess., pp. 55, 56.]

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The region embraced in Captain Pope's explorations is thus divisible into three portions, differing very considerably in their physical configuration. We have, first, the mountain ranges, with their intervening plateaux, extending from the valley of the Rio Grande to the Pecos; secondly, the elevated plateau of the Llano Estacado, from the Pecos to the Sulphur springs of the Colorado; and, thirdly, the descent or slope from this plain over the undulating and fertile valleys of the Texan rivers to the Red river at Preston.

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CHAPTER II.

Geology of the Mountain Ranges.

Ranges probably granitic with Carboniferous limestone.—Organ mountains.—Hueco mountains.—Los Cornudos.—Polished rocks.—Guadalupe mountains.—Trend towards the Witchita mountains.—Sierra de los Alamos and Los Cornudos.—Probable shallowness of the valleys in the granite.—Natural tanks or reservoirs of water.—Similar tanks in the African deserts.—Probable origin.

I DO not find many specimens from the mountain ranges in the collection, and their geological characters along the route are, therefore, not very fully represented. These ranges are the southern continuations of those bordering the valley of the Rio Grande, opposite Albuquerque and Santa Fé, and which are known to be composed chiefly of granite and gneiss, with overlying Carboniferous limestone bearing the usual fossils. The observations of the gentlemen connected with the United States and Mexican boundary commission at the south of the Guadalupe Pass, have shown that the southern prolongation of the chain, from which the Guadalupe range diverges, is composed chiefly of granitic rocks; the presence of Carboniferous limestone and eruptive rocks has also been shown at the southern end of the Organ mountains, near El Paso and Fort Bliss.

Organ mountains.—I do not find many recorded observations upon the rocks which compose the Organ mountains, or the *Sierra de los Organos*—so called, it is said, from the fancied resemblance of the highest peaks to the pipes of an organ. Captain Marcy states that they are of Trap formation, and somewhat columnar in structure, with the columns standing vertically, and in some cases rising to the height of a thousand feet, and terminating in sharp points.[1]

The southern part of this range is, however, known to be granitic, and to be partly composed of Carboniferous limestone, which, perhaps, presents mural faces; and these, seen from a distance, might be mistaken for bluffs of trappean rock. There are two small specimens of a dark-blue limestone from the Organ mountains in the collection, and they are evidently fossiliferous. They resemble specimens of the Carboniferous or Mountain limestone, to which formation they may be safely referred.

Hueco mountains.—The specimens which Captain Pope brought in from the Hueco mountains show that they are composed of granite; and if the great mass of rock is like the specimens, it is fine-grained and compact, and probably eruptive, not formed by the alteration of stratified rocks. It is, however, possible, and very probable, that the rocks usually called *metamorphic* are present in that range, and the presence of a small mass of white crystalline limestone with the specimens may be regarded as an indication of them. In the Diary of Mr. Byrne, I find it stated that the Hueco mountains at the tanks "are composed of a dark-grey sandstone scattered about in high masses, in the most grotesque disorder and confusion."[2]

I find very nearly the same observation made in the report of Captain Marcy, who traversed the range in 1849. He writes: "The road passes between the two mountains, which approach within a few rods of each other, leaving a level pass, bordered by immense ledges of rocks standing out in bold relief directly over the road. The rocks composing the mountains are

[1] Report on the Route from Fort Smith to Santa Fé, p. 198.

[2] Report of Captain Pope, Appendix A—Diary of J. H. Byrne, p. 53.

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large masses of dark-grey sandstone thrown up in the utmost disorder and confusion, having numerous holes and caverns which have often served the Apaches as hiding-places."[1]

It is not impossible that these dark-grey blocks, although resembling sandstone, were the compact and fine-grained granite just described, or possibly Carboniferous limestone. Mr. Byrne afterwards states that the natural wells of the Cornudos were, as at the Hueco tanks, reservoirs in the rock, which was similarly piled up in confusion and disorder. He also states that these rocks are of a kind of granite or gneiss. Mr. Bartlett, the former boundary commissioner, who examined the Hueco mountains carefully, found them to be composed chiefly of granite. He says: "The formation here is granite in place, rising from 100 to 150 feet above the surrounding plain, and covered with large boulders piled up in every imaginable form. In many places, the rock projects or overhangs; and in others, frightful chasms, as though rent asunder by some violent concussion, appear."[2] At other places he found the deep, circular holes in the rock, made by Indians in pounding their corn; and these were in granite, and from twelve to fifteen inches deep. Such holes as these are exceedingly common in California, and are always in the most compact granite, as, undoubtedly, any granular rock like sandstone would be constantly abraded and fill the meal with grit. The descriptions which Mr. Bartlett gives of the overhanging rocks with their broad, flat surfaces, upon which many inscriptions have been made, indicate the presence of stratified rocks, although it is not at all improbable that such surfaces are presented by the masses of granite. When travelling through the Hueco Pass, however, Mr. Bartlett mentions the occurrence of grey limestone, which rose up on each side of the way like walls. At the same time, the great mountain could be seen half a mile beyond, with perpendicular sides of granite.

From these facts, and other evidences, I conclude that the Hueco mountains are principally granitic and metamorphic, and that stratified rocks occur on the flanks of the range; whether these are the Carboniferous strata, or not, it is of course impossible to decide without specimens and fossils.[3]

The peculiar broken character of this granite, the masses being of great size, and lying piled together in confusion, has resulted from the gradual breaking up of the mass *in situ*, and not from the action of floods, by which the blocks have been transported like boulders to their present positions. It is probable that the whole mountain is traversed by fissures in several directions, so that the whole rock is, in a manner, cut up into blocks, which become loosened and detached by weathering, and roll down its sides, accumulating in rude piles around the base of the cliffs.

Los Cornudos.—According to Mr. Byrne, this mountain is about five hundred feet high, and consists of huge masses of rock, scattered about in the utmost disorder and confusion. It was also his opinion, as has already been stated, that they were composed of a kind of granite or gneiss. I find the following observations on this rocky elevation in the narrative of Mr. Bartlett: "This wonderful mountain, of which it is impossible to convey any adequate idea by description, is a pile of red granite boulders of gigantic size, thrown up abruptly into the plain. The boulders are mostly of an oblong shape, with their largest diameter vertical; they are rounded, and often highly polished."[4] It is evident that, in respect to the broken, loose character of the rock, it much resembles that of the Hueco mountains at the wells, and, like it, appears to be a quantity of boulders piled together. This, as I have shown, arises from the decomposition of the rock, and its gradual breaking up along lines of fissure or of cleavage. Mr. Bartlett's description will apply very truthfully to an erupted rock somewhat basaltiform; and I am inclined so to regard it. Moreover, I find in the collection one specimen from this locality—No. 73 of the catalogue and description. The label states that it was taken from the

[1] Report on the Route from Fort Smith to Santa Fé, p. 199. [2] J. R. Bartlett, Personal Narrative, i, p. 170.

[3] Lieutenant Bryan states that the rocks on each side of a part of this pass are in regular layers, and consist of limestone and granite. [Reconnaissances in New Mexico and Texas, p. 23.]

[4] J. R. Bartlett, Personal Narrative, i, p. 129.

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vicinity of Los Cornudos, (Thorne's wells.) It is a peculiar porphyritic rock, of a light-grey color, with a faint shade of lilac. It is evidently eruptive, and may be called trachyte, the feldspar being in glassy crystals, and apparently imbedded in a less crystalline base of the same mineral. Hornblende is present in small black crystals, and a small hexagonal plate of dark-red mica is also visible. It is entirely different from the granite found at the Hueco mountains, and its characters are more nearly like those of recent erupted rocks, such as occur in dykes, and not in broad, extensive masses.

Mr. Bartlett noticed a peculiarly polished surface on all the rocks of that locality; in one place, it was so distinct that it appeared "to have been done by the hand of man." (p. 130.) This phenomenon was again presented near the Hueco tanks, where are some isolated granite precipices standing alone in the plain; the surface was so highly polished, that Mr. Bartlett remarked it particularly, and says that they were as smooth "as if they had been submitted to some artificial process. It was probably the effect of their exposure for ages to the weather."[1] I have very little doubt that this peculiar polished condition of the surface is precisely like that of the rocks on and around the Colorado desert of California. There, the rocks, as I have shown in a recent report,[2] receive their smoothness and high polish by the long-continued action of the grains of sand and of dust which are carried over their surfaces with velocity and force by the winds. This is probably the cause of the polished surface of the rocks of the mountains under consideration. On the desert, the climate is such that there is little or no perceptible disintegration of the rock, even after ages of exposure. This is peculiarly favorable to the production of the polished surface; for the cause is continually acting, and there are no opposing influences.

Guadalupe mountains.—The specimens from the Guadalupe mountains are all of limestone and sandstone, and I do not find any of the erupted rocks represented. From the general topographical indications, I am led to regard this range as having a granitic axis, or as being on the crest of an uplift of granite and the allied rocks, although they may not appear upon the surface. The specimens (particularly Nos. 5 and 6, see catalogue and description,)[3] are, however, of stratified rocks; and in the absence of any evidence of the presence of the Plutonic rocks, I have not represented them upon the map or section at the point crossed by the trail. The peculiar divergence of the mountains towards the northeast, and their apparent prolongation in the Witchita mountains, which has already been noticed, and the connexion of the range on the south with a range known to be granitic, together with its great elevation and rugged character, lead me to consider it highly probable that granite will ultimately be found in some parts of the range, north or south of the part explored. Although there are no fossils in the specimens of limestone from the Guadalupe, and thus there is no evidence of the age of the rocks, I cannot but regard them as Carboniferous, and I have colored the range near the trail accordingly.

This opinion is strengthened by the following description, by Col. A. B. Gray, of the Guadalupe peak, which rises on the north side of the Pass: "There is an abrupt and precipitous cliff of columnar rock upon vast limestone terraces, attaining a height of 1,000 to 1,500 feet above its base, with a general elevation of several thousand feet above the plain. It can be seen at a great distance, owing to the clear and rarified atmosphere of the country. The face of this stupendous structure is perpendicular, and looks as if it had been shaped by some sudden and powerful convulsion of nature into the form of a large edifice or church, from which we gave it the name of Cathedral rock. Viewed from the deep gorge below, it is truly sublime and beautiful; its lofty peak towering to so great an altitude, and crowning the terminal point of an extensive range of mountains."[4] Messrs. Bartlett and Marcy give similar descriptions of this locality, and there is little or no doubt of the stratified character of the mountains.

[1] Bartlett, p. 175.

[2] Preliminary Geological Report in connexion with the report of Lieut. R. S. Williamson. See also the final report.

[3] For a description of these specimens, see a subsequent portion of this report.

[4] Report of A. B. Gray. [Railroad Record: Cin., October, 1855, vol. iii, whole No. 136, p. 13.]

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The plain between the Hueco and the Guadalupe mountains is broken by several short ridges or isolated mountains of moderate height, and shown on the map under the names of *Sierra de los Alamos*, *Sierra Alto*, and *Los Cornudos*. As these mountains are probably all granitic, we may conclude that the foundation of granitic rock, or its subterranean surface, is not far from the surface of the plain; or, in other words, that the valleys in the granite are comparatively shallow, and that there is not a very great thickness of stratified or palæozoic formations resting in them. The topography and the probable Carboniferous strata of the Guadalupe mountains lead me to consider this highly probable, and to regard the country between the two ranges—the Hueco and Guadalupe ranges—as a broad axis or summit of granite and metamorphic rocks overlaid by sedimentary accumulations, similar to those of the Llano Estacado.

Natural tanks or reservoirs of water.—The natural tanks or wells which were visited are an interesting and peculiar feature, and seem to be placed in those desert plains for the comfort of the traveller. These tanks are found principally in the Hueco mountains, but occur at Los Cornudos and other similar localities. The tank in the Hueco mountains, near the trail, is described by Mr. Bartlett as a great cavity in the rock, containing about fifty barrels of pure, sweet water. This cavity was covered by a huge boulder weighing some hundred tons, and its lower surface was only four or five feet above the water.[1]

It is difficult to understand by what action the rocks, if of granite, were symmetrically hollowed out so as to form these well-like reservoirs. It would seem, from some of the descriptions, that they were in sedimentary rocks or strata of sandstone; and, if so, decomposition may have been the principal cause of their formation. Large cavities and irregularly-formed depressions are very common on the surface of granite—and probably this is the character of the tanks—the water being overshadowed and preserved from rapid evaporation by piles of rocky *débris*. Mr. Byrne states in his Journal that the water is not found in the tanks alone, but that there are numerous holes and crevices in the mountains, which contain enough for the use of travellers. This would indicate that the water collects in the irregular depressions of the rock, and not in holes worn out by the action of running water.

Similar reservoirs of water were found in the mountains of the African deserts by Bayard Taylor, who describes one in the Beyooda desert, as a vast natural hollow in the porphyry rock, in the centre of a basin or valley near the top of the mountain. "The water is held in a tank; it is from twenty to thirty feet deep, and as clear as crystal. The taste is deliciously pure and fresh."[2]

It is very probable that some of these reservoirs are constantly fed by the condensation of moisture upon the surrounding rocky summits; and others may be springs supplied through fissures in the rock, the evaporation from the surface being so rapid as to prevent their overflow. A great quantity of water is derived from the melting of snow which falls on these mountains and on the surrounding plains in the winter season.

[1] Bartlett, Personal Narrative, i, p. 134.

[2] Journey to Central Africa, &c., by Bayard Taylor, p. 414, 10th edit.: New York, 1854.

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CHAPTER III.

Geology of the Llano Estacado and the Plateaux between the Mountain Ranges, from the Rio Grande to the Colorado.

Horizontal character of the strata of the Llano.—Section of the strata.—Absence of bluffs.—Character of the strata underlying the Llano.—Gypsum and red clays.—Probable Cretaceous age of the upper strata of the Llano.—Fossils.—Cretaceous at Doña Ana.—Possible presence of Tertiary strata.—Absence of Jurassic fossils.—Red sandstone and Gypsum formation of Delaware creek and the Pecos.—Gypsum of the Andes and Iowa.—Of Nova Scotia and Virginia.—Of Tuscany, Italy.—Extent of the American formation.—Geology of the plains between the Rio Grande and the Guadalupe mountains.—Sand-hills.—Saline lakes.—Springs.—Artesian wells.

THE regular horizontal character of the Llano, and the form of its river valleys, are sufficient, without further evidence, to satisfy the geologist that it consists of horizontal strata of rock; a conclusion which is supported by the observations of all who have visited the region. The sketches of the borders of the Llano, accompanying the report of Captain Marcy, all show, with beautiful distinctness, the stratification of the rock in horizontal planes. So also the sketches brought in by Lieutenant Whipple exhibit successive layers of rock cropping out on the sides of gorges and cañons, and again resting upon the tops of mounds, in broad, table-like summits. Dr. G. G. Shumard, the geologist who accompanied Captain Marcy in his expedition to the sources of the Red river, has described the horizontal strata of the Llano, and we are indebted to him for the first geological section of the formation. This section was taken at the borders of the plateau, near the south fork of the Red river, in latitude 34° 30′, where the bluffs have a height of 600 feet above the prairie below. The base of the bluffs was formed of a deposite of red clay 400 feet thick, with a layer of saccharoid gypsum twenty feet thick above it; this was surmounted by strata of grey and yellow sandstone, alternating with thin seams of non-fossiliferous limestone; and the upper stratum, about 100 feet thick beneath the soil, is of drift with small boulders.[1]

As on the line of survey there were no abrupt or precipitous borders to the Llano, the opportunities for observing the character of the strata were not as favorable as are presented further north. Mr. Byrne, in his Diary, under date of March 6th, mentions the occurrence of gypsum along the borders of Delaware creek, and the next day he describes several caves in gypsum. Lieutenant Marshall, who examined the Pecos river as high up as the Sacramento, reports that the country over which he passed was a rolling prairie, and the soil was a mixture of clay and decomposed gypsum, evidently resting on a bed of limestone, and on a conglomerate of limestone and clay, which outcrops at several points along the river. "On the left or east bank of the river is the broad plain of the Llano Estacado, which evidently has for its basis the same conglomerate rock mentioned above."[2] He also found red clay and gypsum on the banks of the Sacramento river. Captain Pope also mentions immense outcrops of gypsum and selenite in "bluff banks fifty feet high along the Pecos;" and states further, that "numerous caves of pure gypsum of dazzling whiteness within, are found in this gypsum formation, which extends over a distance of 150 miles along the route."[3] From these facts, and the configuration of the Llano, I am led to regard its substrata as similar to those further north, where it has been more

[1] Report of an Exploration of Red river in 1852, by Captain Marcy. [Appendix D, Geology, p. 168, pl. 10.]

[2] Report of Captain Pope, p. 65. [3] Ibid, p. 28.

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thoroughly examined. According to Lieutenant Whipple and Mr. Jules Marcou, the geologist who accompanied him, the base of the Llano along the Canadian is composed of the red and blue clays or marls containing gypsum; above them are white and yellowish sandstones and limestones, also in horizontal strata.

The geological age of these strata of red clays, sandstones, and gypsum, has not yet been satisfactorily determined; the formation appears to be singularly devoid of fossils, and, as yet, the only indications of its place in the geological series are its mineral characters and relative positions. The age of the overlying rocks of a lighter color is also obscure, but there is much reason to regard them as Cretaceous and Tertiary. The only fossils which I find in the collection from the Llano are Cretaceous, and serve to indicate the development of that formation at the Big springs of the Colorado, and a point on the Llano twenty miles east of the Sand hills. There are no fossils from the gypsum formation, nor any specimens which serve as a guide to its age. The fossils referred to are well preserved specimens of *Gryphœa Pitcheri* and *Exogyra Texana;* several specimens of limestone from the bluff at the Big springs of the Colorado, which contain a small *Gryphœa* like *G. vomer;* and a mass of shells much broken, but containing fragments of *Gryphœa* from a point twenty miles east of the Sand hills. Descriptions of these fossils will be found accompanying this report. They are all characteristic of the Cretaceous formation; *Gryphœa Pitcheri* being a well-known fossil of wide distribution in the Cretaceous formations of the United States. The altitude of this locality of Cretaceous fossils at the Big springs, according to the profile from the Pecos to the Big springs, is 3,844 feet above the sea.

The existence of the Cretaceous formation in the valley of the Rio Grande, between El Paso and Doña Ana, has been determined by Major Emory, by observations in connexion with the United States boundary survey. That part of the valley has an elevation of near 4,000 feet above the sea, and the west edge of the *mesa* opposite Doña Ana is 4,460 feet, which, according to the profile, is about the mean elevation of the Llano Estacado. The identification of horizontal Cretaceous formations at this point, at the same elevation with the formations of the Llano, also horizontal, is good evidence of their similarity in age. We have, therefore, three points at nearly the same elevation, yet separated by many miles, which are shown to be Cretaceous by the fossil remains. Two of these localities are upon the Llano, and the other is on the Rio Grande river, and the elevation of each is that of the general surface of the Llano in that latitude. It would appear, therefore, that its upper strata are of the age of the Cretaceous. Further observations and collections of fossils from the plain are, however, very desirable to verify these indications and probabilities.

The specimens of the rocks from the Llano Estacado have a general resemblance to each other, and show the nearly uniform nature of the geological formation. They consist, for the most part, of light-colored, whitish, or grey calcareous sandstones, with specimens of compact amorphous limestone, which resembles the specimens containing the Cretaceous fossils from the Big springs. Three or four specimens consist of sand and gravel united by a calcareous cement, and looking as if these materials had been exposed to the infiltration of water highly charged with carbonate of lime. (See descriptions and catalogue Nos. 23 and 24.) These have a very modern aspect, and much resemble the sandstones and conglomerates of the Tertiary age. Indeed, all the specimens of the sandstones of the Llano are so much like those of the Tertiary, that if it were not for the presence of the Cretaceous fossils, I would have been led to regard them as of that period.

Mr. Jules Marcou, who passed over the Llano with Lieutenant Whipple, near the parallel of 35°, regards the base of the Llano, or the formation of red clays, sandstone, and gypsum, as of the age of the Trias, and the upper strata—the light-colored sandstones and limestones—as Jurassic. In the preliminary observations he made upon this route, based upon Captain Pope's notes and collections, and published in the preliminary 8vo. edition of his report, he assigns the same ages to the corresponding parts of the Llano on the line; and says that the rocks covering the variegated marls of the Trias, and forming the whole plain of the Llano

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Estacado as far as the Pecos river, belong to the Jurassic epoch. I do not find in the collection any specimens or fossils which present evidence of the existence of these formations, and I do not know the foundation for Mr. Marcou's assertion.

The collection which Captain Pope made along the banks of Delaware creek is entirely different in character from that made on the Llano. The color of the sandstones is not light buff and grey, but is red; and the frequent occurrence of the specimens of opaque and transparent gypsum shows clearly that the creek has worn its way downwards in the great gypsum formation. This is also true of the Pecos, for it is indicated by the specimens; and Captain Pope has described a great bed of gypsum, which appears along its banks, and is fifty feet thick.[1] This is said to be translucent, and sufficiently so to be used by the people of New Mexico instead of glass. Captain Pope also states, in addition, that "numerous caves of pure gypsum, of dazzling whiteness within, are found in this entire gypsum formation." This indicates that a large part, if not the greater portion of this great bed, is the opaque amorphous variety. This is truly an enormous bed, and exceedingly interesting in many points of view. Much thicker deposites are, however, found in South America, along the western slope of the Andes, where, according to Mr. Darwin, beds of gypsum alternate with red sandstone and shales, and, in some instances, are not less than six thousand feet thick.[2] Thick beds are also found in the Carboniferous formation of Iowa, where, according to Dr. Owen, the beds are from twenty to thirty feet thick.[3] The enormous deposites of gypsum in Nova Scotia are well known as the sources of the vast quantities used in agriculture and the arts in the United States. These deposites occur among the shales and sandstones of the Carboniferous period, and are well described in a recent volume by Mr. Dawson.[4] The gypsum is found there in many varieties, in thin seams of selenite, in reddish and fibrous veins, and in opaque and amorphous masses; often containing anhydrite in seams and crystalline nodules. In the district of Colchester, on the Shubenacadie, there is an immense mass of gypsum, named White's or the Big Plaster rock, which once presented a "snowy front of gypsum, nearly 100 feet in height;" but which has been greatly reduced by the operations of the quarry-men, who bring down enormous quantities by blasting.[5] The great deposite at Plaister Cove, Cape Breton, contains a bed which Mr. Dawson estimates at fifty yards in thickness.[6]

Extensive deposites of gypsum are also found in the Preston Salt valley of Virginia, where, according to Prof. H. D. Rogers,[7] it occupies an extensive fault or break in the Umbral or Carboniferous strata of that region.

According to W. J. Hamilton, esq.,[8] the great gypsum beds of Italy, which furnish the masses of beautiful alabaster used for various ornamental purposes, are found in the Tertiary strata of Tuscany, associated with a blue marl. Fossils of the genera *Dentalium*, *Cardium*, *Venus*, *Cerithium*, *Pleurotoma*, *Turritella*, and a large *Ostrea*, occur in the formation. The gypsum occurs in detached, irregular masses of great size, and also in continuous beds. Regular strata are found near Castellina, where it is mined extensively. The beds have a slight inclination, and consist of regularly-alternating strata of blue clay and grey gypsum; the latter containing nodules or spheroidal blocks of the pure white alabaster. He states: "In the

[1] Report of Captain Pope, p. 28. [2] Darwin's Voyage of the Beagle.

[3] With respect to these beds, Dr. Owen makes the following statement: "For thickness and extent, this is by far the most important bed of plaster-stone known west of the Apalachian chain, if not in the United States. It is seen at intervals for three miles, exposed, on both sides of the Des Moines, in mural faces of from eighteen to twenty-five feet, always overlying pink shales, from beneath which copious springs of excellent water issue. It has been traced in the ravines, back from the river, for nearly three-quarters of a mile, where it is finally lost under the deep alluvion of the vast plains that stretch away to the west. There is every reason to believe that it occupies an area of from two to three miles square, retaining an average thickness of twenty feet; perhaps double that thickness at certain points." [Report of a Geological Survey of Iowa, Wisconsin, and Minnesota. By Dr. D. D. Owen: Phil., 1852, p. 126.]

[4] Acadian Geology. By J. W. Dawson: Edinburgh, 1855. [5] Ibid, p. 232. [6] Ibid, p. 279.

[7] Report on the Salt and Gypsum of the Preston Salt Valley of Virginia. By Prof. H. D. Rogers: Boston, 1854.

[8] Quarterly Journal of the Geol. Soc. Lond., vol. i, p. 273.

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shaft of the mine, I observed five distinct beds of gypsum alternating with the blue clay, and varying in thickness from five to twenty feet."[1]

The formation which was partly traversed by the survey, although, perhaps, equalled in the thickness of the beds by other localities, is nevertheless the most remarkable for its extent, and for the number and variety of the gypseous beds of all degrees of transparency and of many colors. Captain Pope observes that it extends over a distance of one hundred and fifty miles along the route. It was found along Delaware creek, the Pecos, and again at the sources of the Colorado, at the eastern margin of the Llano. The same formation is largely developed along Red river and the Canadian; and the explorations of Captain Marcy and of Lieutenant Whipple have added greatly to our knowledge of its character and extent in that direction. Captain Marcy, in a letter to Professor Hitchcock in 1852,[2] observes that he has "traced this gypsum belt from the Canadian river, in a southwest direction, to near the Rio Grande in New Mexico. It is about fifty miles wide upon the Canadian, and is embraced within the 99th and 100th degrees of west longitude. Upon the North, Middle, and South forks of Red river it is found, and upon the latter is about one hundred miles wide, and embraced within the 101st and 103d degrees of longitude."

With regard to the geological age of this interesting formation, we are yet without full and satisfactory evidence. Observations on this subject, and additional remarks upon the gypsum, its uses, value, &c., will be found in a subsequent portion of this report.

Plains between the Rio Grande and the Guadalupe mountains.—It is difficult to form a satisfactory conclusion regarding the geological character of the plains between the Guadalupe, the Hueco, and the Organ mountains. The collection is without specimens from the strata underlying this part of the route. It is only possible, therefore, to infer the geology from the topography and the general character of the regions as compared with the adjoining plains, the geological character of which is already indicated by fossils. These determined points are the Llano Estacado on one side, and more particularly the well-known Cretaceous plains of the Rio Grande, at Doña Ana, on the other. This locality of the Cretaceous was well determined by the collections of the United States boundary survey, many Cretaceous fossils having been obtained. The elevation of the locality is nearly that of the plains under consideration; and I am led to infer that they are formed of Cretaceous strata, and have so colored them on the map. Further explorations of the region will, perhaps, lead to the discovery of Tertiary strata overlying the Cretaceous, and the exact limits of the formations will only then become known.

Sand hills.—Hills of dry, blown sand, appear to be a prominent characteristic of the surface of the Llano, and must greatly add to its desert-like and barren appearance. From the Diary of Mr. Byrne, it appears that they were encountered before reaching the Llano, and on the west side of the Hueco mountains. Between camps 11 and 12, on the plateau between the Hueco and Guadulupe mountains, a long belt of sand hills was also found, and the wagons travelled for seven miles at their base. Smaller hills were also seen for a long distance from camp, all composed of fine white sand. But these accumulations of sand do not compare in magnitude or extent with those encountered on the broad Llano, where, according to the same observer, the hills extend for fifty miles from north to south, with a breadth of fifteen miles from east to west. This is the great accumulation of sand on the Llano, and forms a conspicuous feature on the map; it is certainly the most extensive accumulation yet known in the interior; the belts of sand hills on the Colorado desert of California being much inferior in magnitude. In the remarks of Captain Pope upon the Llano Estacado, he states that the Llano is bordered on the south by a range of sand hills of white drift-sand, absolutely destitute of vegetation, and rising seventy feet above the general level of the plain. He further observes: "These hills, over a distance of thirteen miles, present steep ascents through short distances in many places; and the loose, moveable character of the sand, and its depth, render the passage through it with

[1] Quart. Jour. Geol. Soc. London, vol. i, p. 282.

[2] See Report of Captain Marcy—Appendix D.—Geology by Prof. Hitchcock, p. 172.

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wagons next to impossible. On approaching from the east or west, these hills bear every appearance of the sand ridges along the coast of South Carolina and Florida, and the first hard wind will destroy the traces of the most numerous party."[1] Mr. Byrne states an interesting fact, that water is found in abundance among these hills, resting in basins of the purest sand. It appears that water could be at any time procured by going about half a mile from the road among the hills. This fact is somewhat difficult to explain, but it is probable that the water occupies a depression in the subjacent rock, and that it serves to retain the sand as it blows over the plain; and the sand, in turn, protects the water from the complete evaporation which would probably result if the surface was fully exposed to the air. The fact that the sand hills have accumulated in that place, shows the existence of some natural obstacle, or a peculiar configuration of the surface; for when driven before the wind, sand does not come to rest, except under the lee of some obstacle. In all cases where sand progresses before the wind in drifts, one of the slopes—that towards the wind—is more gentle than the other; that slope turned from the wind, or on the lee side of the drift, being the most abrupt. This sand is doubtless derived from a superficial covering of drift upon the Llano, or from the sandstone strata. Mention is frequently made of a hard gravelly surface before the belt of sand hills was reached, and I do not doubt that this sand is swept out from the gravel and small boulders by the wind, and perhaps derived in part from the disintegration of the soft sandstones of the upper part of the mesa. This view is supported by the examination of the specimen of the sand which Captain Pope brought, in No. 77. It is very clean and white, and consists chiefly of silicious grains, much rounded by attrition. They are colorless, and some are transparent. When treated with chlorohydric acid, effervescence takes place, and continues for some moments, showing the presence of a considerable amount of carbonate of lime. This indicates that the sand is derived from the decomposition of the white calcareous sandstone of the region. The sand of the hills on the Colorado desert also contains a very considerable amount of carbonate of lime. It is probably derived from the calcareous cement which invests the pebbles, forming a conglomerate on the surface of the plain, above the alluvial formations of the Desert. This conglomerate is Tertiary, or Quarternary; and the sand is swept from it by the wind, leaving a clean surface of pebbles, like a pavement.

Saline lakes.—A very peculiar and interesting feature of the surface of the Llano and the table-lands west of the Guadalupe range, is the presence, in the lowest parts of these plains, of shallow ponds or lakes, which are generally sulphurous or saline. Of this character are the Mustang springs, consisting of several lakes or pools with highly saline water. The *Ojo del Cuerbo*, or Crow spring, at the western base of the Guadalupe Pass, is in connexion with two small lakes covering four or five acres of ground, which are sulphurous; and about one and a half mile west of them two salt lakes are found.[2] Mr. Byrne also describes a dry salt lake, two and three-quarters miles across, near camp 22 on the Pecos river. It was covered with a salty efflorescence, and, on digging through it and the soil to a depth of two and a half feet, water was obtained highly charged with salts.

It thus appears that lakes or ponds of this character are quite numerous on the Llano, or in the vicinity of the route. Captain Pope's general observation doubtless gives the true explanation of the origin of most of them. He states that they were dry in the month of March, but that they probably contain water during the rainy season. The salt is derived from the substrata or porous rocks of the plain, being dissolved out by the rain water in its percolation through them, or passage over the surface; thus, each successive evaporation of the water in the low grounds adds to the accumulation of salt.

I find in the collection a specimen (No. 72) taken from the bed of one of the salt lakes, 15 miles west of the Guadalupe mountains. It is a light, porous earth, nearly white, and resembling some forms of travertin. It crumbles readily in the fingers, and dissolves partially in chlorohydric acid with violent effervescence. The solution thus obtained contains a large quantity of car-

[1] Report of Captain Pope, p. 9.

[2] Report of Captain Pope—Diary of J. H. Byrne, p. 55.

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bonate of lime, a little magnesia and alumina, with traces of oxide of iron. A large insoluble residue remains. The specimen is apparently a remnant of a rock—probably a silicious limestone—altered by the action of sulphuric acid.

Small salt ponds and dry lake-beds incrusted with white salt, are very common on the plains and valleys of California, especially in the vicinity of Tertiary strata. It is possible that some of the deposits Captain Pope observed have a similar origin; but there is no evidence in the collection of the existence of Tertiary formations. The drift deposit, which has been described by Doctor Shumard as covering the rocks of the Llano, may, and very probably does, belong to the age of the Tertiary; but the materials and facts that were procured by Captain Pope are not sufficient to warrant any conclusions on this point.

Springs.—Other sources of these accumulations of saline water, and which appear to be very common in the region examined, are the springs at different points of the route, which, for volume and persistence of flow, are truly remarkable for that region, which is so arid and desert-like. Several of these springs are in direct connexion with salt lakes or ponds. The Ojo del Cuerbo has already been mentioned, and another example is found in the Big springs of the Colorado, which, according to Captain Taplin, "issue from a ravine on the northeast slope of a range of hills 200 or 250 feet high, whose general direction is S. 45° E. At a distance of one and a half mile, the outlet of the springs joins the valley of the salt lakes, and becomes at this point dry. Many of these lakes contain water; the beds when we passed being moist, and the water totally unfit for use."[1]

He again observes, in relation to a valley about eight miles from the Mustang springs, that it contains at its northwest extremity a chain of salt lakes, "which have a course a little south of east, their outlet passing only a mile and a half east of the Big springs of the Colorado, which are tributary to it." At the northern extremity of the same valley, the outlet to the Sulphur springs of the Colorado joins this chain of lakes. This Sulphur spring is described as "at least fifteen or twenty feet deep, and about twenty yards wide."

Captain Pope's observations on the springs and lakes or ponds of Delaware creek, are interesting in this connexion. He describes the creek as a "succession of small lakes, ten or fifteen feet deep, connected by a swift running stream." "It has its source in a limestone bluff, about fifty feet above its valley, and issues from the base of the bluff from seven or eight springs both pure and mineral. The largest of the pure springs bursts boldly out of the north side of the hill in a stream as large as a barrel, and, after a course of probably fifty yards, it unites with the small streams from the mineral springs. These springs contain sulphur in various proportions—in some barely perceptible, while in others it gives out an odor which is sufficiently perceptible at fifty yards. There are six of these sulphur springs. From the south side of the bluff issues a spring strongly impregnated with soda, and all the springs uniting in one of the small lakes or ponds of Delaware creek form a compound detestable both in smell and taste. The animals, to my surprise, greatly preferred this lake to the pure water of the spring."[2]

Prof. James C. Booth has made some interesting observations upon the specimens of the water from these springs, which were submitted to him by Captain Pope, and the results are found in the table appended to his report.[3] It appears that they contain very considerable quantities of sulphide of sodium and common salt. The earth which Captain Pope collected, and which had a sulphurous odor, I have had examined, and it was found to contain over 18 per cent. of sulphur.[4] Alumina, oxide of iron, lime, magnesia, and sulphuric acid were found in the aqueous extract.

Captain Pope also describes the Independence springs, sixteen miles from the head of Delaware creek, as bursting out from the surface of the ground in a small valley or depression of the table-lands. There are two springs, and by their union they form a small stream, which becomes dry a few miles below. "These springs are about five feet in diameter, and, although

[1] Report of Captain Pope, p. 78.
[2] Report of Captain Pope, p. 30.
[3] Report of Captain Pope, Appendix C, p. 95.
[4] See description, under the head of "Sulphur."

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a pole ten feet long was thrust into them, the bottom was not reached." Five miles further west another spring was found, and still another large one four miles beyond, which gave rise to a stream.

Lieutenant Garrard reports numerous localities of good water at the eastern base of the Guadalupe range, south of Captain Pope's main line of survey. He found it in natural tanks, about thirty-five miles southwest from the head-springs of Delaware creek, and in several water-holes. These were all filled with rain-water, and, from its quantity and other appearances, it was considered probable that a supply would be found at all seasons of the year.[1]

Artesian wells.—The frequent occurrence of springs with such a volume of water as Captain Pope describes, shows the existence of vast quantities of subterranean water, which probably flows below or between the nearly horizontal strata of the Llano. In fact, it would appear that the Colorado and Brazos rivers, or their affluents, which take their rise at or in the borders of the Llano, are supplied by springs gushing out in the ravines. These facts are of great value and importance, and leave scarcely a doubt that water can be obtained on the Llano by boring. The nearly horizontal or slightly undulating position of the strata, and the variation in their mineral character which is known to exist, especially the alternation of compact beds of limestone, sandstone, and clays, present all the requisite conditions for retaining the water under pressure. All descriptions of the strata of the Llano agree in placing at their base a thick formation of red clay, and above it more sandy and porous rocks. We have, therefore, in the clay an impervious substratum, serving to retain the subterranean water in the more porous beds above. These pervious beds are believed to alternate with impervious ones, and thus the underground flow of water is confined. In order, however, that water should rise to the surface, or overflow from artesian borings, the strata which confine it must be inclined, or formed into basin-shaped depressions, so that one portion of the water-bearing stratum is higher than the point pierced by boring. On the Llano the strata, although described as horizontal, doubtless present not only a considerable degree of inclination towards the east and southeast, as shown by the gradual inclination of the surface, already described; but flexures or extended bends and depressions in the strata doubtless exist. Such variations from a horizontal plane are found in every extended sedimentary deposite, even where the strata have not been disturbed by convulsive changes of the earth's crust. Indeed, a perfectly horizontal mass of strata over broad areas is unknown to geologists. The occurrence of the dry salt lakes and the ponds on the surface of the plain; the depressions which become filled with water during the rainy season only, all indicate the existence of corresponding depressions in the underlying strata. I do not find any evidence in Captain Pope's observations, or in those of his party, to justify me in the conclusion that the strata of the Llano are upheaved, dislocated, or distorted by the uprising of the Guadalupe mountains. This appears to be Captain Pope's impression, based, perhaps, upon the statement of Mr. Marcou, who did not visit the district Captain Pope explored. The configuration of the Llano, its topography and generally level character, are, to me, insurmountable objections to this view. The intrusion or the uplift and folding of such a mass of mountains as the Hueco range and the Guadalupe, in whatever manner it took place, would have produced most decided flexures and abrupt folds of the strata of the Llano, so as to completely destroy its character as a plain. The configuration of the region is opposed to the opinion that the mountain ranges are more recent than the strata of the Llano. A disturbance of this nature is not, however, necessary, as has already been shown, to the production of the uneven condition of the strata requisite for obtaining water by boring. The gentle inclination of the plain and the strata from the mountains eastward, amounting in the whole breadth of the Llano to at least 400 feet, according to Captain Pope's measurements, is sufficient to give water at the surface of the eastern margin from a depth equally great, provided the permeable strata were fully charged, and the water did not suffer retardation by friction. It is possible, however, and indeed most probable, that the difference of elevation is much greater than 400 feet; and, if so, water could

[1] Report of Captain Pope—letters of Lieutenant Garrard, p. 63.

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be obtained at the surface from a correspondingly greater depth. We must not expect to gain water at the surface from a depth greater than the difference between the elevation of the western edge of the Llano and the point of boring. This observation is made on the assumption that it is to the western edge of the Llano alone to which we must look for the supply of water. It is possible that the strata are supplied with water from the northern or northwestern borders of the Llano, and in this case water may be obtained from depths much greater than those mentioned. The difference of elevation of the plain from north to south is not yet known, but, as we have already shown, it is probable that the surface gradually rises from the south towards the north and west, although the measurements along the 35th parallel, when compared with those of Captain Pope, do not exhibit a very striking difference of elevation.

It is very possible that water-bearing strata may be found nearer to the surface than the underlying clay formation—the red marls and clays of the gypseous series; and that basins and depressions of the strata, of a comparatively local character, will furnish water at the surface from a slight depth. To me, the existence of the springs at the borders of the Llano is the best evidence that is presented in favor of the presence of water in the strata. Its configuration alone does not appear remarkably favorable to the success of deep artesian wells.

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CHAPTER IV.

Remarks on the Geology from the Llano Estacado to Preston.

General description of the country.—Red sandstone and gypsum.—Age of the Gypsum formation.—Absence of fossils.—Probable Carboniferous or Cretaceous age.—Gypsum of Nova Scotia in the Carboniferous.—Fort Belknap to Preston.—Section of strata.—Coal.—Carboniferous limestone.—Cross Timbers.—Cretaceous.—Loess.

THIS portion of the survey embraces a strip of country extending in a northeasterly and southwesterly direction, and over 300 miles in length. I cannot better introduce the few observations it is possible to make on the geology, than by quoting the general description of the section given in Captain Pope's report:

"The space between the eastern base of the Staked Plain and the Red river, at the parallel of 34°, is occupied by that portion of northern Texas drained by the tributaries of the Colorado, the Brazos, the Trinity, and the Red rivers. With rapidly-increasing advantages as you proceed eastward from the Llano Estacado, this region is well timbered, well watered, and possessed of a soil of extreme fertility, capable of sustaining a dense population. The entire country is so gently undulating in its surface, and presents such an abundant and well-distributed supply of wood and water, that it can be traversed in any direction with trains of wagons, and is of so genial a climate that little choice of the seasons is considered desirable in undertaking an expedition through it. A great portion of the timber of the region intersected by the Colorado and its tributaries, along this route, is the mezquite, which, about thirty feet in height, and from six to ten inches in diameter, divides about equally with the prairie lands this entire district of country. The Brazos and its tributaries are better supplied with oak timber of a larger size, the country is more undulating, and the water more abundant. Immense coal-beds, of good quality, crop out along the valley of the river, and every advantage of soil and climate is offered to the emigrant. A military post (Fort Belknap) has been established upon this stream, near the 33d parallel. But by far the richest and most beautiful district of country I have ever seen, in Texas or elsewhere, is that watered by the Trinity and its tributaries. Occupying east and west a belt of one hundred miles in width, with about equal quantities of prairie and timber, intersected by numerous clear, fresh streams, and countless springs, with a gently undulating surface of prairie and oak openings, it presents the most charming views, as of a country in the highest state of cultivation; and you are startled at the summit of each swell of the prairie with a prospect of groves, parks, and forests, with intervening plains of luxuriant grass, over which the eye in vain wanders in search of the white village or the stately house, which seem alone wanting to the scene. The delusion was so perfect, and the recurrence of these charming views so constant, that every swell of the ground elicited from the party renewed expressions of surprise and admiration."[1]

A vivid contrast is here presented by this beautiful and fertile region with the arid plateau of the Llano; and the change is coincident with the marked variation in the configuration of the country. The difference in altitude is not alone the cause of the change; the character of the soil is doubtless very different from that of the Llano; and this, with the number of streams giving abundance of water, and the climatic conditions incident to a lower level and greater proximity to the Gulf, are sufficient to explain this extraordinary fertility.

[1] Report of Captain Pope, p. 9.

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The observations on the nature of the strata of this portion of the survey are very few, and I cannot, therefore, present many remarks upon them. In the Diary of Mr. Byrne, under date of April 15th, bluffs of red sandstone at the crossing of the Colorado are mentioned. Again, on one of the tributaries of the Brazos the Gypsum formation is mentioned, and its resemblance to that of Delaware creek is noted. April 19th, Captain Pope passed over a bluff or bank showing limestone and red sandstone in horizontal strata, with decomposed gypsum strewed thickly about. The water, too, was strongly impregnated with gypsum, or probably with salts of magnesia. From these facts, and the peculiar topography and the vegetation, I conclude that, from the time of leaving the Llano, at the springs of the Colorado, east, to the vicinity of the Clear fork of the Brazos, the route was upon the red sandstone formation, containing the enormous deposits of gypsum, and underlying the lighter-colored sandstones and limestones of the Llano—the continuation, in fact, of the same deposits which were traversed along the Pecos and Delaware creek, already noted and described. The quantity of gypsum, however, which is met with in this part of the formation, does not at all compare with that found on the Pecos, but the characteristic peculiarities of the formation were preserved.

Age of the Gypsum formation.—As in the first part of this report no observations upon the geological age of the Gypsum formation were presented, I now propose to briefly consider this subject, before passing to a description of the rocks around Fort Belknap, and from thence to Preston.

Much light has already been thrown upon the geology of this region by the labors of Doctor G. G. Shumard, in connexion with the exploration made by Captain Marcy.[1] The Red-sandstone and Gypsum formation has also been described by President Hitchcock;[2] but he does not decide upon its age, both from the absence of fossils, and the want of sufficient observations upon its position relatively to other formations, the age of which is well determined. For the same reasons, I shall not attempt to establish its geological age. Its position relatively to the Carboniferous formation, which it overlies, indicates that it may belong to the upper portion of that series. It may also be of Permian or Triassic age, to which formations it bears great resemblance in its mineral characters. It may also be Cretaceous, and fossils of this period only, have been brought from that region. That it is of the age of the Trias is the opinion of Mr. Marcou, who traversed the formation along the Canadian river with Lieutenant Whipple; and in the preliminary report on Captain Pope's collection, which he prepared, he distinctly states it to be Triassic, and overlaid by Jurassic strata. We have already seen that the evidence of the geological age of the upper strata of the Llano favors the conclusion that they are Cretaceous; and there is no evidence or indication of their Jurassic age, nor is there in the collection any fossil from the underlying red clays and sandstones by which their age can be established. Dr. Shumard, in his geological section from Arkansas to Fort Belknap, has represented the Cretaceous strata at Fort Washita as resting directly upon the coal-measures; and Professor Tuomey, the geologist of the State of Alabama, finds them in the same position, and without any intervening Triassic or Jurassic strata. The section which Dr. Shumard presents does not show whether the Cretaceous strata correspond in dip, or are conformable with the coal-measures below; nor is it easy to decide, from the descriptions, whether the coal-measures are horizontal or have a slight dip. An outcrop of bluish-grey limestone, about one hundred miles southwest of Fort Smith, is said to dip at an angle of 30°. A ridge of granite succeeds, and then sandstone is found nearly to Fort Washita, where it is covered over by the Cretaceous strata. The Carboniferous sandstones at Fort Belknap are described as nearly horizontal. It would thus appear that the Cretaceous formation of that region is found to lie conformably upon nearly horizontal Carboniferous strata. If this is true, may we not consider the red clays and sandstones of the Gypsum formation, upon which the Cretaceous of the Llano rests, as portions of the Carboniferous series? It is true, we are entirely without adequate data upon

[1] See Report of Captain R. B. Marcy, of an Exploration of the Red River in 1852—Appendix D, Geology, p. 179.

[2] Ibid, p. 164.

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which to base an opinion or conclusion respecting the part of the Carboniferous series to which these strata may be referred; but, whether upper or lower, the group, if Carboniferous, differs materially from the Carboniferous formation as developed further to the north and east. The same difficulty arises if we consider the Gypsum formation as Triassic; the same apparent deficiency of strata, well characterized at other localities, exists.

There are many reasons for referring the formation to the age of the Cretaceous, for this is the only period represented by fossils; and from the wide extent of the strata, we are compelled to believe that they attain a very considerable thickness—a thickness greater than that of the light colored strata of the Llano above the red clay and gypsum. The whole series, from the surface of the Llano, of Cretaceous age, down to the underlying Carboniferous sandstones, might be regarded as Cretaceous. If we admit the mineral characters of the strata as evidence of the age of the formation, they will favor the conclusion that it is Carboniferous.

Dr. D. D. Owen (as has already been noted, page 18,) reports the existence of great beds of gypsum in the Carboniferous shales of the coal-basin of Iowa; the beds being from twenty to thirty feet thick. So, also, the great beds of Nova Scotia, which supply such large quantities of massive gypsum and alabaster for exportation, are in the Carboniferous formation, and not in the new red sandstone, or "Trias." Mr. Dawson, in his recent able and interesting work, entitled "Acadian Geology," gives detailed descriptions of these beds, and of their association with the marls, sandstones, and limestones of the coal period. The well-known gypsum-beds of Windsor, Nova Scotia, are found in connexion with a limestone containing fossils of the lower Carboniferous formation, of the genera *Productus*, *Spirifer*, and *Terebratula*. Mr. Dawson makes the following observations in regard to the position of the gypsum: "Above this limestone, in the order of succession, we have alternations of marls and limestones, and next a bed of white crystalline gypsum, contrasting strongly in its purity and whiteness with the other beds of mere mechanical origin. Here the shore becomes low, and no rock is seen; but a little to the eastward we find the great gypsum quarries of Windsor, excavated in the outcrop of a very thick bed, the strike of which would bring it to the shore just where our section fails, and where the gypsum has been removed, partly by the river, and partly by the quarrymen who earliest dug this rock for exportation. A little further to the southward, at the next bluff point, there is a very thick bed of limestone, filled with, or rather made up of, fossil shells of various species and genera, affording a remarkably perfect display of the shelly coverings of creatures that inhabited the Carboniferous seas."[1] The following species are enumerated, and figures given: *Productus Lyelli*, *Fenestella membranacea*, *Terebratula elongata*, *Ceriopora spongites*, and new species of *Orthoceras*, *Spirifer*, and *Conularia*. The bivalve shells are very numerous, especially four or five species of *Terebratula*, three of *Spirifer*, and three of *Productus*. The Carboniferous age of this Gypsum deposit is thus established; and I have been particular to present the evidence upon which the conclusion is based, as Mr. Jules Marcou, who regards the red marls and gypsum of New Mexico as Triassic, has affirmed their synchronism, or connexion with the Nova Scotia deposits of Windsor and Plaister Cove.[2]

I do not regard the physical and mineral characters of a formation as sufficient to establish its geological age, or relative position in the scale of palæozoic formations. In the absence of fossils, I do not, therefore, assign the age of the Gypsum formation; but its relative position, and its mineral characters, unite in showing it to be Carboniferous, or Cretaceous, rather than Triassic.

Fort Belknap to Preston.—According to Dr. Shumard,[3] the geological formations in the vicinity of Fort Belknap consist of nearly horizontal strata of fine-grained sandstone, shale, and soft, drab-colored, non-fossiliferous limestone, whose relative positions correspond with

[1] Acadian Geology. By John William Dawson: Edinburgh, 1855, p. 218.

[2] Report of Explorations for a Railway Route, &c., by Lieutenant A. W. Whipple. House Doc. 129: Washington, 1854, p. 42.

[3] Report of Captain Marcy of Exploration of the Red River in 1852.—Appendix D, p 182.

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strata of the same character, largely developed between Fort Washita and Fort Smith. He also gives the following section, taken at a point about one mile from the fort:

1. Arenaceous subsoil of a red color; thickness ---------- 3 to 10 feet.
2. Black shale, soft, and rapidly disintegrating ---------- 4 "
3. Seams of bituminous coal, from ---------- 2 to 4 "
4. Fine-grained sandstone of a yellowish-grey color, and containing fossil ferns; thickness variable.
5. Grey non-fossiliferous limestone; thickness unknown.

A number of seams of bituminous coal, varying in thickness from two to four feet, have been opened along the river, and the coal made use of at the fort. Dr. Shumard also states that the characteristic fossil ferns of the Carboniferous era have been found with this coal, and considers the age of the formation established.

I learn from Colonel Loomis, the commanding officer at Fort Belknap, that there is an abundance of hard blue or grey limestone about three miles below the fort, and that a quarry has been opened there, and several thousand bushels of good lime burned from the rock. It would appear that the Carboniferous limestone occurs at this point; and I am confirmed in this opinion by a *Productus* which was taken from the quarry.[1] The Carboniferous age of the coal is thus rendered more certain. Further observations on the coal will be found in Chapter V of this Report.

Between Fort Belknap and Preston, the remarkable belts of wooded country, known as the Upper and Lower Cross Timbers, indicate a change of soil, if, indeed, they do not mark out the borders of a geological formation. Dr. Shumard found that the Cretaceous formation developed at Fort Washita was continuous to the southwestern margin of the Cross Timbers.[2] I find in the collection several fragments of *Gryphœa*, a Cretaceous fossil, from the Elm fork of the Trinity; and a mass of broken shells, probably of *Exogyra Texana*, also of Cretaceous age, from the banks of Red river, near Preston. From these facts, I have ventured to conclude that the route was upon the Cretaceous, from the western margin of the Cross Timbers to Preston, and have so indicated it upon the map and section.[3]

From the preceding observations, it appears that, after leaving the strata of the Llano Estacado, on the western border of the Colorado river, the route was upon the Red-clay and Gypsum formation until it reached the Clear fork of the Brazos, where it is probable the coal-measures commence, and continue to a point a few miles east of Fort Belknap, and are then succeeded by Cretaceous strata to the termination of the line of exploration at Preston, on the Red river. There is nothing in Captain Pope's report to indicate the exact boundary or limit of the coal-measures between Belknap and the Gypsum formation; and I have been guided by the topography alone in assigning this line to a point near the intersection of Captain Pope's trail with the Clear fork of the Brazos.

The great fertility of the soil found through this region is thus explained by the number of the geological formations, all traversed by numerous streams and their tributaries, which transport and mingle the detritus from all the strata, so that a soil of complex composition is produced. It is more than probable that formations more recent than the Cretaceous are developed along the line east of the Colorado. We should expect to find horizontal strata of the Tertiary period imposed upon the Cretaceous beds, but the collection does not indicate that the formation was passed over.

[1] I am indebted to Mrs. Loomis for this fossil, which removes all doubt of the Carboniferous age of these deposits.

[2] Marcy's Report, p. 181.

[3] I have marked the boundary of the Cretaceous as far west as the western margin of the Cross Timbers with some reluctance, as the general statement of Dr. Shumard does not permit the limit of the formation to be accurately plotted; and I have been led, from a consideration of the position of the outcrops of Carboniferous limestone, to consider that the Carboniferous strata were extended in a northeasterly direction from Fort Belknap for several miles beyond the first or most western belt of Cross Timbers—the Upper Cross Timbers. In the absence, however, of any more definite information, I have been guided by Dr. Shumard's statement.

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Dr. Shumard found on the Red river, twenty-six miles from Fort Washita, a deposit of ash-colored loam, twenty-five feet thick, containing terrestrial and fluviatile shells of the genera *Lymnea Physa, Planorbis, Pupa,* and *Helix;* the whole resembling species found in the loam at New Harmony, Indiana, and elsewhere in the Mississippi valley.[1] This formation along the Mississippi constitutes what are known as the "Bluffs," and is a fluviatile accumulation laid down by the river when the region was at a lower level. In other words, it is an ancient alluvion. Its thickness and known extent along the Mississippi render it very probable that it will be found along most of the principal tributaries of that river. A similar deposit is found along the valley of the Rhine. Its thickness is from 200 to 300 feet, and it is a yellowish-grey loam, consisting chiefly of clay, combined with sand and carbonate of lime. The same deposit is found along most of the principal valleys or tributaries of the Rhine; it evidently having been contemporaneously deposited. It is known in Germany under the name of *loess.*

The occurrence of a formation along the Red river similar to those described, leads me to believe that it will be found along most of the rivers which are tributary to the Mississippi, and it is quite probable that, in the environs of Preston, and even over broad tracts of that region, there are extensive superficial alluvial deposits, which afford a soil that can scarcely be surpassed for its richness and fertility.

[1] Report of Captain Marcy—Appendix D, p. 183.

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CHAPTER V.

Building-stones.—Coal.—Gypsum.—Lead.—Sulphur.

I.—BUILDING STONE.

Description of the principal specimens in the collection.—Remarks upon them and their distribution.

I PRESENT under this head a brief description of some of the most interesting rock-specimens in the collection, especially those indicating deposits which can be made use of for purposes of construction. These specimens are described according to their numbers in the catalogue, and the same descriptions will serve the purposes of the geologist.

No. 3. *Granite from Hueco mountains.*—This is a very fine-grained and compact grey, sienitic granite, the crystals of hornblende being very small, and appearing as small black grains. The feldspar is white and glassy. A fragment of white limestone accompanies these specimens.

No. 5. *Limestone from head spring of Delaware creek.*—This is a very compact, dark-colored rock, and breaks with a conchoidal fracture. The weathered surface is grey. When struck, or if cut with a knife, a peculiar bituminous and offensive odor is produced.

Nos. 6 *and* 8 are similar to No. 5.

No. 17. *Limestone from foot of Guadalupe mountains.*—This is a very compact, firm rock, of a greyish-white color, and sub-crystalline grain—saccharoidal. It contains some slight cavities, rendering it somewhat porous, but it may be regarded as a good and elegant building material.

No. 9. *Sandstone from Guadalupe mountains.*—This is one of the firmest and hardest sandstones in the collection. It has an even grain and pleasing drab color, but weathers with a dark, rusty brown surface. The mass, when held in certain positions, reflects the light as if from a cleavage surface of carbonate of lime. It effervesces violently with chlorohydric acid, and is, evidently, highly charged with carbonate of lime.

No. 36. *Sandstone from Llano Estacado.*—This specimen much resembles No. 9, but is more compact, and probably contains more lime. The brilliant reflections noticed in No. 9 are very evident here, and are manifestly due to a partial crystallization of the carbonate of lime. The color of this specimen is a rusty brown, and darker than No. 9.

No. 27. *Sandstone from east side of the Pecos.*—This is a firm, compact specimen, of a uniform grain, and sufficiently tough for building purposes. It does not, however, look very durable.

No. 30. *Sandstone from Llano Estacado.*—This specimen is coarse-grained and quite friable. It contains a notable quantity of carbonate of lime, and probably is not very durable if exposed to the weather. It resembles the Tertiary sandstones of the Bernardino Sierra, California.

Nos. 19, 20, 23, 24. *Sandstones.*—These specimens have a general resemblance. No. 23 has a reddish color, due to the presence of oxide of iron, but in other respects it much resembles No. 30, and, like it, may be crumbled away by the fingers on the thin edges. No. 19, from near the river, is peculiar. The little grains of sand are cemented by a thin white crust, which is carbonate of lime; and when the grains are crumbled out, small cavities are left in the calcareous mass. No. 20 is similar, but contains same large pebbles. No. 24 has the same general characters, but is much coarser. All these specimens have a modern look, and resemble the Tertiary sandstones along the margin of the Colorado desert, where some of the upper beds are highly charged with carbonate of lime in the form of travertin, or calcareous tufa.

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No. 59. *Sandstone, from head waters of the Colorado.*—This is a very fine-grained red sandstone, resembling in texture and color the red sandstone of New Jersey and Connecticut. It is friable, and small fragments may be crumbled in the fingers.

No. 52. *Sandstone, from south side of the Brazos.*—This is a fine-grained stone of a light-grey color, and sufficiently compact and tough for ordinary building purposes. This specimen contains a large per centage of carbonate of lime.

No. 53. *Sandstones from head waters of the Colorado.*—These two specimens are alike in grain and hardness, but differ in color; one is red, and the other grey. They are not very tough, and both contain a large portion of carbonate of lime.

Nos. 56 *and* 57. *Ferruginous sandstone, from between the head waters of the Trinity and the Brazos.*—These specimens are interesting from the quantity of oxide of iron which they contain. The iron oxide appears to be the cementing material, and constitutes the principal portion and weight of the specimens. They are both very hard, and are not easily broken, but are not suitable for building purposes.

No. 69. *Ferruginous conglomerate, from near Fort Washita.*—This specimen is very rich in iron, and, indeed, may very properly be called an iron ore. Its association, however, with the silicious sand is not favorable for the manufacture of iron. It is not at all suitable for buildings.

No. 51. *Conglomerate, from affluent of the Trinity.*—This specimen is interesting, inasmuch as the material by which the pebbles are held together is *silex*. This silex invests each pebble, and fills up the spaces between them; it has a semi-opaline character, and in some places successive layers on the walls of the cavities are visible, showing a structure like agate. The silex has evidently been deposited by the infiltration of silicious water, which has thus produced a hard, firm rock. The specimen is a good illustration of the extent to which rocks may be changed and modified in their chemical and physical characters by the slow and quiet agency of infiltration of water holding foreign substances in solution.

It is thus evident that a considerable variety is found in the building materials along Captain Pope's route. The light-grey colored sandstones, however, appear to predominate, and are found at several points. The specimens of the best quality were from the following places: Guadalupe mountains, (where there is also limestone of good quality;) Llano Estacado, thirteen miles east of the Sand-hills, (No.36;) on the east side of the Pecos, (No. 27;) south side of the Brazos, (No. 52.) From the Hueco mountains the specimens of granite are very fine, and show that a very superior building-stone can be obtained there. It is by far the best building material in the collection, and probably can be obtained in any desired quantity. I believe, however, that many localities of sandstone will be found at convenient points along the route; and although many may not be of the hardest and toughest description, they are sufficiently firm and compact to endure for long periods in favorable situations. At Fort Belknap building-stone is not readily obtained in large quantities at any one point. When the quarters were in process of erection, considerable difficulty was experienced for want of good stone, and that which was used was taken from many different places, at a distance of one-half to one mile from the post.

The limestone which occurs a few miles down the river furnishes excellent caustic lime, and over 2,000 bushels have been burned there. I judge, from the descriptions, that good building-stone could be procured at the quarry.

The limestone specimens from the Llano do not give much promise; they are not sufficiently homogeneous and compact.

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II. COAL.

Fort Belknap.—Carboniferous formation.—Lignite on the Brazos.—Probable extent of the coal.

The only locality of coal mentioned in Captain Pope's report is that at Fort Belknap, on the Brazos, and which has already been noticed in a general way (p. 27). There are no specimens of this coal in the collection, nor of any other from other localities. I learn, however, from Col. Loomis, the commanding officer at Fort Belknap, that this coal is of fair quality and burns freely, leaving a white or grey ash. It does not cause any trouble by slaging. This coal has been in use at that post for a long time, and excavations over twenty yards deep are already made into the bank, on the course of the vein or bed. The vein is horizontal, and about four and a half feet thick, and is divided in the middle by a thin layer of slate from one to four inches thick. It is found at many places along the river, and several places have been opened into, and good coal taken out. A layer of hard blue clay is found under the bed. An attempt to procure water by a well about sixty feet deep, which was made by General Belknap, at a point three-quarters of a mile from the river, resulted in the discovery of a bed of similar coal, which is probably the continuation of the same bed. When the coal was reached, the well was abandoned. The coal is taken from the mine in large blocks and masses, but when exposed to the air they fall to pieces.

Dr. G. G. Shumard is very positive in his opinion that this coal is of the true Carboniferous period, and says that it is characterized by the fossil ferns of that era. The description of the adjoining strata seems to indicate a more recent age for this deposit; in fact, according to the descriptions of the strata, they more nearly resemble Tertiary than Secondary deposits. Dr. Hitchcock has observed this, and in his report to Captain Marcy says: "Now, at first view, it would seem almost certain that we have here a description of a genuine coal formation of the Carboniferous period, not less than three hundred and fifty miles long, associated, moreover, with those valuable iron-ores which, in other parts of the world, are connected with such deposits; for, in descending through the formation, we find, first, overlying shale; then, coal; then, coal sandstone, or perhaps millstone grit; and then, perhaps, Carboniferous limestone. But it is well known that coal occurs in other rocks besides the Carboniferous, as in eastern Virginia in Oolitic sandstone, and in other places in Tertiary strata. These more recent coals are often of great value, as in Virginia, but they are not generally as good as those from the Carboniferous strata. It becomes an important question, therefore, to determine to what geological period the coal under consideration belongs. A few specimens of the fossil ferns would decide the matter, and I trust that Dr. Shumard is right in referring them to the Carboniferous era; but it is well known that analogous species occur in the higher rocks; and so coal, even in the Tertiary strata, is sometimes more or less bituminous. The evidence, however, appears to me to be strong in favor of this deposit being of the Carboniferous age. But in your letter of April 1st,[1] you state some facts respecting this coal that have thrown a little doubt over my mind. You say that 'the coal formation of the Brazos is found in a coarse, dark sandstone rock, which is a solid stratum, but is easily removed in consequence of being so soft. In excavating for a well, we passed through the sandstone and the coal. The greater part of the stone was removed with the mattock; and in the coal, which was here about sixty feet below the surface, we found fossil ferns, which, unfortunately, were not preserved.' The ease with which this sandstone was removed, requiring only a mattock, corresponds better with the hardness of Tertiary than of Carboniferous rocks; yet, in some parts of the world, distant from igneous rocks, the sedimentary strata are but little indurated."[2]

Beds of lignite or Tertiary coal are found at many places in Texas. A bed, four feet thick, is found on the Colorado river, near Bastrop, beneath a layer of Eocene fossils.[3] It also occurs on the Brazos, at the mouth of the Little Brazos. These localities are, however, nearly two

[1] Letter from Captain Marcy.

[2] Report of Captain Marcy, pp. 164, 165.

[3] Verbal communication from Dr. Moore, of Texas. June, 1855.

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hundred miles distant from Fort Belknap, and probably have no connexion with the deposit at that place. It appears to me most probable that Dr. Shumard's opinion is entirely correct, and that the coal of Fort Belknap is of the Carboniferous era. The occurrence of the Carboniferous limestone in the vicinity, as shown by the *Productus* already mentioned, renders the Carboniferous age of the coal nearly certain.[1] It is most probable that this coal deposit is of great extent, underlying a broad area in Texas, and extending into New Mexico, under the great *Llano Estacado*, and possibly outcropping on the eastern flanks of the Hueco and Organ mountains.

III. GYPSUM.

General description of the mineral.—Its composition and uses.—Anhydrite.—Varieties of Gypsum in the collection.—Description of a specimen containing carbonate of lime.—Gypsum of Plaister Cove, Nova Scotia.—Applications of gypsum in the arts.—Quantity mined and sent to the United States.—Remarks on the origin and formation of the beds.

The geological peculiarities and relations of the Gypsum deposits which were passed during the survey, have already been described in the preceding portions of this report. The great extent of the deposit, however, and the wide distribution of the material, demand more than a consideration of its geological position and characters, as compared with other deposits. The peculiar and varied forms under which the gypsum appears, the phenomena of its formation, and its economical value, should be considered. As this Report will fall into the hands of many who are not familiar with the composition and properties of the mineral, I present a partial mineralogical description of the species and its varieties.

The mineral species *Gypsum* consists of sulphuric acid, lime, and water, combined, when pure, in the following proportions:

Sulphuric acid ($S O_3$)	46.51
Lime ($C_a O$)	32.56
Water ($H O$)	20.93
	100.00

Its formula is $C_a O, S O_3 + {}_2H O$. It crystallizes in beautiful transparent crystals, which belong to the monoclinic system, and are found with various modifications. These crystals may be split (cleaved) very readily in one direction, into beautiful and perfectly transparent thin plates, like mica, but not elastic, which are sometimes used instead of glass. These crystals are very soft, and may be scratched by the finger-nail, being a little softer than rock salt, or 1.5—2 on the scale of hardness adopted by Mohs. The specific gravity (of crystals) is about 2.3, being less than the gravity of carbonate of lime or limestone. It occurs of various colors, generally white, but sometimes grey, flesh-red, honey-yellow, ochre-yellow, and blue; while impure varieties are of various shades of black, brown, and red. It dissolves, without effervescence, in chlorohydric acid, and is soluble in 500 parts of pure water.

It appears in nature under many different aspects, as will be seen from the number of colors given above. It has also many varieties of form, being found in the small and perfect crystals; in broad thin plates, like glass; in fibrous masses, with a peculiar silky lustre; and in granular masses of different degrees of fineness of grain, both translucent and opaque. These varieties have received different names; the transparent plates are called *selenite*, from *selene*, the moon; the fibrous masses are called *satin-spar;* and the white and fine-grained amorphous varieties, suitable for carving, are known as *alabaster*. The ordinary compact opaque masses, which are

[1] Since the above was written, I have received a collection of fossils from the vicinity of Fort Belknap, made by Dr. Shumard, when with Captain Marcy, on his exploration of the country of the Witchita Indians. These fossils consist of two or three species of *Productus* and *Terebratula;* there are also many *Encrinites* and *Cyathophyllæ*, and a *Pleurotomaria*, from the coal-bed. They were collected at Belknap, and nine miles below, and at a point forty miles west. I have therefore marked the Carboniferous limestone on the map at these places.

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used in agriculture and the arts, are very generally known under the name of gypsum, or *plaster;* which latter name, however, is more appropriate when applied to the powdered mineral.

When the masses of gypsum are heated, the water which is in combination is given off, and they are converted to a dry, white powder, like flour, which is called *plaster of Paris*, and has the important property of hardening when mixed up with a small quantity of water. The operation of expelling the water is called "boiling," although no water is used in the operation. The escape of the water in the form of steam keeps the mass in continual agitation.

Sulphate of lime also occurs in nature without any water, and forms another mineral species, called *anhydrite*. This has the following composition in 100 parts:

Lime (C_a O)	41.2
Sulphuric acid (S O_3)	58.8
	100.0

It is generally found associated with gypsum, and the two species are often found to pass into each other, forming a compound, with a smaller quantity of water than pertains to gypsum.

Captain Pope observed many of these varieties of gypsum on the line of survey, and it is possible that beds of anhydrite were also passed. The specimens which I find in the collection consist of the pure, transparent selenite (Nos. 7 and 25); a red, fibrous variety (No. 15); and a new and peculiar mass (No. 14), which is different from any hitherto described.

The descriptions already given of selenite will suffice for Nos. 7 and 25, but No. 14 deserves more than a place in the catalogue.

The specimen is about five inches long and two thick, and was taken from the banks of Delaware creek. It at first appears to be a stratified mass, being marked with regular lines like the divisions between strata. The main portion of the mass is white, opaque, and amorphous gypsum, but it is in combination with transparent selenite.

The white amorphous portions are in thin and parallel layers, about one-tenth of an inch thick, and they are separated by thin sheets of a different color, and about as thick as a stout card. The examination of these thin sheets shows them to consist of carbonate of lime. This result, which was unexpected, is very curious and interesting, and the formation of the mass cannot be readily explained. On the weathered surfaces of the specimen these layers of carbonate of lime are more distinct than on a freshly fractured surface, appearing at first as if they resisted decomposition better than the sulphate. A closer examination shows that the decomposition is most rapid at the line of junction between the carbonate and the gypsum, so that both layers stand out from the surface.

The transparent selenite, which traverses this mass, cuts obliquely across the opaque layers, both of the gypsum and the carbonate, cutting them off like a dyke traversing stratified rocks. Some of the layers of carbonate are, however, found in the mass of the selenite, preserving their parallelism and general characters, but not exactly parallel with the outer layers. The principal cleavage of the selenite is oblique to the layers, being inclined at an angle of about 45°.

An hypothesis which will explain all these phenomena is not easily formed. The whole appearance of the specimen, its stratified character, suggests its origin by successive deposition; but the extreme regularity in the thickness of the layers, and the absence of all granular structure, forbid this conclusion. It may, however, have been deposited from solution in successive layers, and the crystalline portion may have been subsequently formed from the material so laid down. It appears more probable that the whole mass is due to a segregating or crystalline force acting while the solution of lime was diffused in the strata of earth or sand, and bringing the particles together in one seam, as water, during its crystallization, is sometimes separated in layers from a bank of earth or clay.

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Another specimen (No. 13) is very similar to No. 14, but the layers of sulphate of lime are thicker, and the specimen appears to have been broken from a different and a large mass.

The collection made along the 35th parallel, partly in the valley of the Canadian, contains several specimens from this same extensive Gypsum formation, which are peculiar for their deep-red color and the well-defined crystalline structure, showing that the color is not due to an ordinary mechanical mixture. The greater part of the mineral on the route, especially that on the Pecos, appears to be the white granular variety, the same in which the beautiful white caves are found. Captain Pope, however, mentions the selenite as if it existed in large quantities also. It would be very interesting to determine whether any portion of these beds are of anhydrite, or whether it is found isolated in the strata, apart from the gypsum. The occurrence of large quantities of anhydrite with the gypsum in the Carboniferous strata of Nova Scotia renders the inquiry still more interesting, as another mineral character might be added to the already numerous points of resemblance. I quote from Mr. Dawson's book a description of a part of the gypsum deposit of Plaister Cove: "About two-thirds of the thickness of the bed consists of crystalline anhydrite, and the remaining third of very fine-grained common gypsum. The anhydrite prevails in the lower part of the bed, and common gypsum in the upper; but the greater part of the bed consists of an intimate mixture of both substances, the common gypsum forming a base in which minute crystals of anhydrite are scattered, and bands in which anhydrite prevails, alternating with others in which gypsum predominates. It is traversed by veins of compact gypsum, but I saw no red or fibrous veins like those of the marl. In some parts of the bed, small rounded fragments of grey limestone are sparingly scattered along layers of the gypsum."[1]

The applications of gypsum in the arts, both in its raw state and prepared, or ground into plaster, are multiplied and various. It is an interesting fact, that selenite was well known to the ancients, who, according to Pliny, made bee-hives out of it, in order to see the bees at work within. According to Dr. Hitchcock, it was used by the wealthy and in palaces for windows, under the name of *Phengites*, and "has the curious property of enabling a person within the house to see all that passes abroad, while those abroad cannot see what passes within. Hence Nero employed it in his palace."[2] The uses of alabaster are well known. Large quantities are worked into ornamental objects—vases, statuettes, &c.—in the establishments of Florence and other places in Europe.[3] The fibrous variety, or satin-spar, is sometimes used for making ornaments and beads, called *Roman pearls*. But by far the most important applications of gypsum in the arts, are those of plaster of Paris. In this state it is used for moulds, casts, statues, as a cement, for plastering walls, and for ornaments on ceilings. The crude, unburnt gypsum, when powdered, is largely used in agriculture as a fertilizer. Enormous quantities of this substance are thus annually consumed in the United States. It is brought from the quarries of Nova Scotia, and finds its way, by rivers, canals, and railroads, to nearly all parts of

[1] Acadian Geology, p. 280.

[2] Marcy's Report, p. 173.

[3] The following description, by W. J. Hamilton, esq., of the gypsum and alabaster mine near Castellina, in Tuscany, is interesting in this connexion:

"We entered the mine by an inclined path, and, passing under ground, soon reached an open well, or large inverted cone, around which the inclined path is carried, and where the section of marls and gypsum is well exposed. As the descending road passes through the third and fourth gypsum beds, galleries are seen striking into the rock in all directions. The first and second gypsum beds are of a uniform character and grey color, and do not contain any alabaster blocks. These are found, principally, in the third and fourth beds, and occur as irregular, isolated, spherical masses, imbedded in the gypsum, from which they are, mineralogically speaking, distinctly separated by a thin black crust, which indicates to the workman the existence of the finer nodules. These nodules are most frequent in the lower part of the stratum, and occur in regular layers, never touching, although varying much in their distances from each other. In bed number 3 there are two layers of these nodules, and in number 4 there are three. They vary much in size, weighing from 20 or 30 pounds to upwards of 2,000 pounds. When the workman discovers the black crust, he is at once aware that he is near a block of alabaster, and, by following the direction of the crust, he removes the gypsum all round until he has nearly detached the whole nodule, which is at last carefully separated from the parent rock. Gunpowder is occasionally used to blast the rock, when no black crust indicates the existence of the alabaster. This crust, in connexion with the pure alabaster, is, perhaps,

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the country. It is even taken in quantities from the sea-board, by railway, far into the interior, to the broad fields of northern Virginia, situated on the new red sandstone or "Trias." Some idea of the extent to which this substance is used in agriculture may be obtained from a knowledge of the amount taken from the quarries of Nova Scotia and New Brunswick, and exported to the United States in 1851. This, according to Mr. Andrews, was 40,592 tons, and valued at $28,145. And in the year 1850, the quantity quarried reached the enormous amount of 79,795 tons.[1] According to Dawson, the quantity quarried in Hants and Colchester districts in 1851 was 78,903 tons, having a value of £10,000 at the ports of shipment, the greater part of which is exported to the United States for agricultural purposes.[2]

It is thus seen that there is an immense and inexhaustible supply of this valuable mineral in convenient proximity to all parts of the Atlantic coast of the United States. It is readily quarried at little cost, and can be loaded directly into vessels without land transportation. This is sufficient to show that the deposits of Texas and New Mexico cannot become valuable as a source of gypsum for export. The expense of quarrying in horizontal beds is greater than in vertical ones, where they are exposed in bluffs; and the distance of the Texas deposits from seaports will confine the use of the gypsum to its immediate vicinity.

Origin of the gypsum beds.—The origin of these great beds of gypsum has excited much speculation, and numerous hypotheses have been formed by different writers to account for their formation. Some suppose the thick beds to have a mechanical origin—they having been deposited at the same time with the adjoining strata, and in a similar manner. Their igneous origin was formerly advocated—the absence of stratification in some beds being regarded as evidence of their once melted or fluid condition, and of their intrusion between the strata, as volcanic rocks or lavas are found to traverse stratified deposits. The doctrine of the chemical character or origin of the deposits is now, however, very generally accepted. Although not now prepared to enter into a full investigation and consideration of this difficult subject, I would remark, that when in California, in 1853, I was led to some conclusions respecting the formation of gypsum beds, by the study of phenomena presented in the Tertiary strata of Ocoya or Posé creek, where beautiful seams of transparent and fibrous gypsum occur.

Veins and layers of oxide of iron, produced by infiltration, are found at that place; also large beds of the same substance where there had formerly been accumulations of fossils, their casts only being left in the firm oxide, while all the lime had been removed. Still further below we find layers of crystalline gypsum, presenting in their structure full proof of an origin subsequent to the deposition of the strata.[3] These conditions were evidently the result of the infiltration of acid waters downwards through the strata; the lime of the shells having been dissolved, and a simultaneous deposition of iron produced.

I am inclined to regard all the great beds of gypsum of the Gypsum formation underlying the Llano as formed by the percolation through the strata of water charged with free sulphuric

one of the most curious features of the mine. On close examination, it appears to be laminar and concentric, and to consist of layers of blue clay and gypsum. Now the whole formation of gypsum contains a small portion of clay, which gives it the greyish color; and it is probable that when that peculiar principle, whether crystallization, attraction, or electricity, which caused the aggregation of the particles of gypsum in greater purity and in a more crystalline state was in operation, one of its chief effects was to expel to the circumference all the particles of argillaceous matter previously mixed up with the gypsum; a process which would continue until either the crust itself opposed a resistance to the further action of this principle, or until two opposing spheres nearly came in contact with each other."

"Very fine crystals of selenite, and sometimes of a large size, are not unfrequently found in the fissures of the gypsum. They are used for the purpose of making the fine scagliola cement, and are consequently sold at a much higher price than the ordinary gypsum. The price of the fine alabaster is 5 Tuscan lires the 100 lbs. Tuscan at the quarry, or 8 if delivered in Leghorn." [Quart. Jour. Geol. Soc. Lond. vol. i, p. 282.]

[1] Andrews's Report on the Colonial and Lake Trade: Washington, 1854, pp. 491 and 493.

[2] Acadian Geology, p. 238.

[3] Other interesting facts and observations upon the gypsum will be found in detail in the writer's forthcoming report of a Geological Reconnaissance in California.

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acid, or with sulphate of iron, derived from the decomposition of pyrites. When such a mixture of acid and water passes downwards through the strata, and comes into contact with carbonate of lime, either disseminated in the strata or in the form of beds, it produces decomposition, and the sulphate of lime is formed, which crystallizes either at the place of decomposition, or at a still lower point, where the gypseous solution accumulates. This accumulation or concentration of the percolating fluid may be caused by the presence of a layer of impervious clay, which prevents its further progress. When the infiltrating fluid is charged with sulphate of iron, a double decomposition ensues, sulphate of lime and carbonate or oxide of iron being formed; the latter being deposited at the point of decomposition as a red or brown powder. The origin of the red marls and sandstones may be thus explained. I do not doubt the formation of many gypsum veins and thin layers in this manner—by the infiltration of acid water, and the subsequent and gradual crystallization of the solution in the strata, separating itself in clear plates from the earthy materials which hold the solution. This is accomplished by the crystalline forces, precisely as water in crystallizing in a bank of earth and sand will separate into clear sheets of ice with such tremendous force as to elevate banks of superposed earth many feet thick. If a thin seam of selenite or ice may be formed in this manner, it is not unreasonable to believe that beds many feet thick may have the same origin. A larger supply of material only is required. Abundance of lime for the formation of such beds would be found in the thick beds of limestone, or, disseminated with the sands and clays of the great mass of the strata. Whole beds of limestone may have been transformed from the carbonate to the sulphate. With respect to the sources of the sulphuric acid, its origin is indicated to us by the highly sulphurous nature of the water constantly being poured out on the surface of the Llano, or in the valleys of the streams on its borders. These waters contain much sulphuretted hydrogen in solution, which, on exposure to the oxygen of the air, becomes converted into sulphuric acid. These springs may have once been much more numerous and powerful, and may have been charged with free sulphuric acid. The water may either have risen to the surface, or permeated the strata from below. Another source of sulphuric acid may have been found there in entombed organic remains, which, by their decomposition, give rise to sulphuretted hydrogen.

I am pleased to find that Mr. Dawson also regards the action of free sulphuric acid upon beds of limestone as the probable cause of the formation of the gypsum beds. In relation to this subject, he makes the following observations: "For the gypsum of Nova Scotia, occurring, as it does, in thick and extensive beds, interstratified with marl and limestone, there appears to me to be but one satisfactory theory—that of the conversion of beds of calcareous matter into sulphate of lime by free sulphuric acid, poured into the sea by springs or streams issuing from volcanic rocks. Modern volcanoes frequently give forth waters containing sulphurous and sulphuric acid. In the volcanic region of Java, for instance, there is a lake of sulphuric acid, from which flows a stream in which no animal can live. The water of this stream being, probably, more dense than sea-water, will naturally flow along the bottom of the sea, and, if it meets with beds of calcareous matter, will convert them into gypsum."[1]

IV. LEAD.

Lead and silver mines of the Organ mountains.—Description of the specimens.—Galena.—Cerusite.

I find several large and fine specimens of lead ores in the collection, but they are without labels. In Captain Pope's Report, however, mention is made of "valuable silver and lead mines" on the west side of the Organ mountains, "extending over a continuous distance of twenty-five miles."[2] He also states that specimens from these mines were obtained and brought in. I therefore conclude that the specimens are from the above locality.

As our knowledge of these mines is so limited, and every fact concerning them is of the

[1] Acadian Geology, pp. 223, 224.

[2] Report of Captain Pope, p. 31.

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greatest interest, especially in connexion with the analyses of the ore, I quote the observations upon the locality given in the Report:

"The want of means to open these mines, and the ignorance of mining characteristic of the New Mexican, have altogether prevented any development of their richness; and it has only been within the last eighteen months that anything like a serious commencement has been made. Mr. Stevenson has opened a mine about fifteen miles from the river, at Doña Ana, and, notwithstanding the impossibility of getting an experienced miner, and the crude and imperfect manner of smelting he has been compelled to adopt, the results have been exceedingly profitable. The ore is powdered between two stones, and the smelting is done without one convenience common to the States. The refuse, probably, contains as much silver as the original ore; and, notwithstanding this, from a mule-load of three hundred pounds of the ore, he gets $18 of silver."[1]

These descriptions will apply to a silver mine rather than to one of lead. The specimens brought in are of lead, and contain but a small portion of silver. It is, however, possible that there is a large quantity of loose friable ore in connexion with the more compact masses, such as Captain Pope obtained, and which is much more rich in silver. Silver is a common associate of lead ores, especially of galena, with which it is so combined that it is generally separated by smelting and cupellation. The following is the description of the specimens:

No. 78. *Galena, from Organ mountains?*—The specimen is a very fine mass of galena, (a sulphuret of lead,) and it contains a small nodule of iron pyrites, and some fragments of carbonate of lead. Galena, when pure, consists of—

Sulphur	13.4
Lead	86.6
	100.0

It crystallizes in cubes and in modifications of the monometric system, the cleavage of which is very distinct in the specimens. This ore of lead generally contains a small quantity of silver, and the specimen is labelled "argentiferous." The specimen was examined by cupellation to determine the quantity of silver. An average of three trials yielded 0.165 per cent., or 48 troy ounces to the ton. It yielded 85.62 per cent. of lead.[2]

No. 79. *Cerusite, (specimen marked "Plomb argentifere,") from the same locality as No.* 73.—This is a mass of compact carbonate of lead, containing some small cavities in which the crystalline planes of the mineral can be seen. The amount of lead was determined as sulphate, giving 72.48 per cent. of the metal. An examination was made for silver, but not a trace could be found.

Carbonate of lead is known in mineralogy under the name of *cerusite*, and, when pure, has the following composition:

Carbonic acid	16.5
Oxide of lead	83.5
	100.0

This mass is remarkably large, and shows that very considerable deposits of ore exist at the locality from which it was taken. The mineral has resulted from the decomposition of the vein, which probably consists of the sulphuret. It is a very valuable ore of lead, and is very easily

[1] Report of Captain Pope, p. 31.

[2] The examination of these specimens for silver was made for me by Doctor J. D. Easter, of Baltimore.

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smelted. This mineral is found in beautiful crystallizations at the Wheatley mines in Chester county, Pennsylvania. It also accompanies the ores of lead in Cornwall and Alston Moor, England, and in Scotland at Leadhills and Wanlockhead.

V. SULPHUR.

Analysis of a powder from Delaware creek.

No. 71. *A greenish earthy powder, from the bed of Delaware creek, at the springs.*—This specimen contains 18.28 per cent. of free sulphur; the residue consisting of sand and clay, with other earthy ingredients in small proportions. The determination was made by igniting a weighed portion, previously dried at 212°, in a porcelain crucible.[1]

An aqueous extract contains:

Alumina and oxide of iron, lime, magnesia, and sulphuric acid.

This quantity of sulphur is sufficient to render the earth very valuable; but its distance from water-transportation and a market is so great, that it probably will not be available even if found in large quantities. From the chemical examination of the waters of the spring by Dr. Booth, it appears that chloride of sodium (salt) is the principal solid ingredient, but considerable quantities of sulphide of sodium are present, and in one the amount was considered equal to the quantity of salt. The water also contains carbonate of soda and sulphates of lime and magnesia.[2] It is probable that the waters, as they issue from the springs, become changed, and their ingredients undergo recomposition on exposure to the air or by mingling together. The waters from the springs examined by Dr. Booth were alkaline, but it is possible that some of the springs are acid; and in this case the precipitation of sulphur would ensue on the mixture of the acid waters with those charged with the alkaline sulphurets, and the origin of the deposit of sulphur in powder would thus be explained.

[1] This examination was made for me by Dr. J. D. Easter, of Baltimore.

[2] See Table III, "Mineral Waters," p. 97 of Captain Pope's Report.

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CHAPTER VI.

Description of the Fossils collected by Captain John Pope.

EXOGYRA TEXANA?

No. 80. *From the banks of Red river, near Preston.*—This specimen is labelled *Ostrea carinata*, from the "*Neocomian*," but consists of a confused mass of fragments of fossil shells, in which the specific characters are completely lost. Traces of plication are visible on one of the edges of the specimen, but they are not sufficiently well defined to permit of a determination of the species. They are not so sharp and angular as in *O. carinata*, but are more rounded, and more nearly resemble the plications of *Exogyra Texana*. If it were possible to identify *O. carinata* in this specimen, it would indicate a Cretaceous age for the deposit, for this species is characteristic of the Lower greensand, Upper greensand, and Chalk marl—the three divisions of the Cretaceous. Its occurrence, therefore, cannot be regarded as an evidence of the Neocomian age of the deposit from which it was taken.

No. 84. *From Big springs of the Colorado.*—This lot consists of three specimens of *Exogyra Texana*, Roemer,[1] a fossil species common in the Cretaceous formation of Texas. It has been obtained by Dr. G. G. Shumard, at the Cross Timbers, Texas,[2] and by Dr. Roemer, in the Cretaceous deposits near Fredericksburg and New Braunfels.

No. 85. This specimen appears to be a valve of *Exogyra Texana*, but it is much worn, and no label was appended showing the locality.

GRYPHÆA.

No. 83. *From the Big springs of the Colorado.*—This lot of shells consists of four specimens of *Gryphœa Pitcheri*, Mort. They are rather small, but are well characterized, and indicate a Cretaceous age for the formation. One of the specimens contains, among fragments of shells adhering to its interior, a portion of a shell resembling a *Pecten*, but its specific character cannot be recognised.

No. 81. This specimen is labelled "Outcrop of horizontal strata, 20 miles east of the Sand hills, on the Llano Estacado." It is also said to form the highest stratified rock. Like No. 80, it consists of a confused mass of fragments of shells, but their characters are more distinct, and *Gryphœa* can be easily recognised. It is, however, not possible to determine the species, but it is probably *G. Pitcheri*.

Nos. 86, 87, 88, 89, *and* 90. *From the Big springs of the Colorado.*—These specimens are granular limestone, friable and porous, and of a light-drab or buff color. They are said to be taken from the base and top, and the intermediate portions of the bluff at the springs. One specimen, from near the base, is more compact than the others, and contains a large amount of crystallized carbonate of lime in little seams. Specimen 89, from near the top of the bluff, contains a small *Gryphœa*, which resembles *G. vomer*, but it is not well enough preserved to be identified. This is the only fossil that can be detected, but the formation may be regarded as Cretaceous.

[1] F. Roemer, Texas, 396; also, Roemer's Kreid. Tex., 69, Taf. x, fig. 1, a–e.

[2] Marcy's Report—Appendix E, 205.

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In the letter of Charles L. Taplin, addressed to Captain Pope, mention is made of ledges of petrified oyster-shells from this locality.[1]

No. 82. *A specimen labelled "Neocomian limestone from the Elm fork of the Trinity river."*—It consists of fragments of *Gryphœa*, firmly impacted together, and so obscure that the species cannot be determined. It resembles *G. Pitcheri*, and in the mineral characters so closely simulates specimens obtained by Major Emory, and containing Cretaceous fossils, that it must be regarded as coming from the same formation. There is certainly no evidence of its being of the age of the Neocomian division.

PRODUCTUS.

No. 91. *From the bed of an affluent of the Elm fork of the Trinity river.*—These two specimens are compact limestone, of a dark color, and much stained with oxide of iron. They are marked by casts of fossils, which, though obscure, are of Producti, and indicate, for the specimens, the age of the Carboniferous. They are, undoubtedly, transported fragments from outcrops of the Carboniferous limestone.

REMARKS.

The fossils which Captain Pope has collected, with the exception of No. 91, are all such as characterize the Cretaceous formation. This formation is well represented by *Gryphœa Pitcheri* and *Exogyra Texana* from the Big springs of the Colorado. These fossils are well known in the Cretaceous formation of Texas. The former was first described by Dr. Morton, of Philadelphia,[2] who received his specimens from the plains of Kiamesha, Arkansas. He also states that he has seen other specimens from the falls of Verdigris river, in the same territory.

These fossils serve to indicate the development of the Cretaceous formation at the following points: Banks of the Red river, near Preston; Big springs of the Colorado; Elm fork of the Trinity river; and a point twenty miles east of the Sand hills, on the Llano Estacado. I have therefore colored these places as Cretaceous upon the map.

[1] Report of Captain Pope, p. 77.

[2] Morton's Syn. Org. Rem. Cret. Groups U. S., p. 55.

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